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Quality Assurance Procedures: Method 28 Certification and Auditing of Wood Heaters

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16. ABSTRACT

Quality assurance procedures are contained in this comprehensive document intended to be used as an aid for wood heater manufacturers and testing laboratories in performing particulate matter sampling of wood heaters according to EPA protocol, Method 28. These procedures may be used in research and development, and as an aid in auditing and certification testing. A detailed, step-by-step quality assurance guide is provided to aid in the procurement and assembly of testing apparatus, to clearly describe the procedures, and to facilitate data collection and reporting. Suggested data sheets are supplied that can be used as an aid for both recordkeeping and certification applications. Throughout the document, activity matrices are provided to serve as a summary reference. Checklists are also supplied that can be used by testing personnel. Finally, for the purposes of ensuring data quality, procedures are outlined for apparatus operation, maintenance, and auditing. These procedures combined with the detailed description of the sampling and analysis protocol will help ensure the accuracy and reliability of Method 28 emission testing results.

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QUALITY ASSURANCE PROCEDURES: METHOD 28 CERTIFICATION AND AUDITING OF WOOD HEATERS

by:

G. D. Rives, M. W. Hartman, and R. C. Olin
Radian Corporation
Research Triangle Park, North Carolina 27709

T. E. Ward
Quality Assurance Division
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

68-02-4119

Project Officer:

Thomas E. Ward
Quality Assurance Division
Atmospheric Research and Exposure Assessment Laboratory
Research Triangle Park, North Carolina 27711

Atmospheric Research and Exposure Assessment Laboratory
Office of Research and Development
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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FOREWORD

Measurement and monitoring research efforts are designed to anticipate environmental problems, to support regulatory actions by developing an in-depth understanding of the nature and processes that impact health and the ecology, to provide innovative means of monitoring compliance with regulations, and to evaluate the effectiveness of health and environmental protection efforts through the monitoring of long-term trends. The Atmospheric Research and Exposure Assessment Laboratory, Research Triangle Park, North Carolina, has responsibility for: assessment of environmental monitoring technology and systems for air, implementation of Agency-wide quality assurance programs for air pollution measurement systems, and supplying technical support to other groups in the Agency including the Office of Air and Radiation, the Office of Toxic Substances, and the Office of Solid Waste.

Emissions from wood heaters are regulated by the Agency, which has published methodology for measurement of these emissions. Proper applications of quality assurance procedures are necessary for production of acceptable data and for determination of the quality of the data produced. This research was undertaken to produce quality assurance procedures for the Agency's Method 28.

Gary J. Foley
Director
Atmospheric Research and Exposure Assessment Laboratory
Research Triangle Park, North Carolina 27711

ABSTRACT

Quality Assurance Procedures: Method 28, Certification and Auditing of Wood Heaters is a comprehensive document intended to be used as an aid for wood heater manufacturers and testing laboratories in performing particulate matter sampling of wood heaters according to EPA protocol, Method 28. These procedures may be used in research and development, and as an aid in auditing and certification testing. A detailed, step-by-step quality assurance guide is provided to aid in the procurement and assembly of testing apparatus, to clearly describe the procedures, and to facilitate data collection and reporting. Suggested data sheets are supplied that can be used as an aid for both recordkeeping and certification applications. Throughout the document, activity matrices are provided to serve as a summary reference. Checklists are also supplied that can be used by testing personnel. Finally, for the purposes of ensuring data quality, procedures are outlined for apparatus operation, maintenance, and auditing. These procedures combined with the detailed description of the sampling and analysis protocol will help ensure the accuracy and reliability of emission testing results.

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INTRODUCTION

Quality Assurance Procedures: Method 28, Certification and Auditing of Wood Heaters has been prepared as an aid for wood heater manufacturers and testing laboratories in performing the wood heater operation procedures specified in Appendix A, 40 CFR 60 (Method 28), and in ensuring data quality and reliability. Method 28 must be used for operation of the wood heater when using Method 5G for determining wood heater emissions. Therefore the user may also refer to Quality Assurance Procedures: Method 5G, Determination of Particulate Emissions from Wood Heaters from a Dilution Tunnel Sampling Location.

CONCLUSIONS

It is concluded that these procedures will be helpful in ensuring and establishing the quality of the data when sampling according to the requirements of Method 28. This will be beneficial for all data producing activities including research and development, and as an aid for certification and auditing. This document may be used in combination with Method 28 for designing an individualized quality assurance program.

RECOMMENDATIONS

Copies of the checklists and summary activity matrices provided herein may be supplied to testing personnel to ensure that the described quality assurance procedures are followed. Also, copies of blank data sheets can aid the user in ensuring and establishing data quality in sampling activities.

SUMMARY OF METHOD 28

Method 28 contains all the requirements and describes the apparatus and procedures for the emission certification testing of wood heaters. For reference purposes only a complete copy of Method 28, Appendix A, 40 CFR 60 (53 FR 5901) is included in Section 9.0 of these procedures. Certification and audit emission tests are a series of at least four test runs which meet the burn rate specifications in Section 5.0 of Method 28. Certification tests performed on a representative wood heater are used to demonstrate compliance with the New Source Performance Standard (NSPS) for particulate matter emissions from residential wood heaters (40 CFR 60.530 et seq.). "The audit emission tests are an enforcement tool for EPA to ensure that production line wood heaters meet the appropriate emission limits." Method 28 describes how to set up the test facility, how to install the wood heater, and how to operate the wood heater during the emission tests. Method 28 also contains procedures for determining burn rates and calculating weighted particulate emission rates, as well as for reporting test results.

Three other test methods are designed to be used in conjunction with Method 28. These are Methods 28A, 5G, and 5H. Method 28A describes the sampling and analysis procedures for measuring the air-to-fuel ratio or minimum burn rate to determine whether a wood-fired appliance is subject to the NSPS. Method 5G describes the procedures for measuring emissions from a dilution tunnel location and Method 5H contains the procedures for sampling from the wood heater flue. Testers have the option of selecting either Method 5G or Method 5H for sampling emissions while operating the wood heater according to the specifications of Method 28.

METHOD HIGHLIGHTS

EPA Method 28 contains all the requirements and describes the apparatus and procedures required for the emission certification testing of wood heaters. The apparatus and procedures are used with various sampling methods (e.g., Method 28A, 5G, and Method 5H). Method 28 is unique in that its purpose is to ensure consistency in wood heater emissions rather than to sample the emissions. For this reason, to get accurate and repeatable emission sampling data, it is extremely important to follow procedures described in Method 28 closely. Following test procedures closely is ultimately to the advantage of both the wood heater manufacturer and the test laboratory.

QUALITY ASSURANCE PROCEDURES HIGHLIGHTS

These procedures, Quality Assurance Procedures: Method 28, Certification and Auditing of Wood Heaters, are to be used as an aid in assembling the testing apparatus, to list and describe the required procedures, and to facilitate the data reporting. Activity matrices are provided at the end of the appropriate sections. For data reporting, Section 11.0 consists of blank data sheets which can be reproduced and used as an aid in data collection and reporting. Examples of the use of these sheets are given in the manual.

1. Procurement of Equipment

Section 1.0 presents the specifications, criteria, and design features for the equipment and materials required to set up and operate a wood heater according to Method 28. This section is intended to inform the user of the apparatus selection options and the rationale for selecting a particular piece of equipment. The activity matrix given at the end of Section 1.0 can be used as a convenient checklist for equipment procurement and initial acceptance check procedures.

2. Calibration

Section 2.0 provides an item-by-item, step-by-step guide to the required calibration procedures and calibration frequencies. Some of the apparatus (e.g., platform scale and moisture content meter) require calibration before each certification test run, while other pieces of apparatus require calibration semiannually.

An activity matrix is provided at the end of Section 2.0 as a summary of the calibration procedures.

3. Pretest Procedures

Section 3.0 describes procedures that are conducted before emission sampling begins. These procedures include firebox volume measurements, wood heater installation, apparatus check and calibration, catalytic combustor and wood heater aging, validation of secondary air adjustments, test fuel measurements and crib construction, measurement of the facility conditions, and presampling burn activities. Illustrations, examples, and an activity checklist are provided to assist testing personnel in performing and documenting pretest procedures. An activity matrix provides a summary of the purpose, specifications, and time and frequency of each pretest activity.

4. Test Run Procedures

Section 4.0 lists and describes the activities performed during the test run. These activities include beginning the test run, measurement of test run data at 10-min intervals, adjustment of fuel and air supply settings, test run completion, and recording of data. An activity matrix is provided listing in chronological order each activity performed during the test run.

Illustrations and examples are provided to assist testing personnel in performing and documenting test run activities.

5. Post-test Procedures

Section 5.0 describes the activities required at the end of the certification test run. These include the measurement of test facility condition parameters, recording the wood heater surface temperatures, and sampling train and equipment leak checks. Recommended procedures also include performing a calibration check on the platform scale and measurement of the fluid level in the liquid seal.

6. Calculations

Section 6.0 describes calculations necessary for performing and reporting Method 28 procedures. Calculations for determining weighted particulate emission rates and dry burn rates and for validating secondary air adjustments are provided. Examples are included.

7. Maintenance

Section 7.0 summarizes recommendations on maintenance of equipment.

8. Auditing Procedures

Section 8.0 describes recommended audit procedures, including both performance audits and systems audits. A table is provided that summarizes these procedures.

9. Reference Method

Section 9.0 contains a copy of Method 28 as proposed in the Federal Register (40 CFR 60.530).

10. References

Section 10.0 provides the reader with a list of the references used in the preparation of this document.

11. Data Sheets

Section 11.0 provides sheets that can be used for calculations, record keeping, and data reporting. These sheets may be removed and duplicated.

1.0 PROCUREMENT OF APPARATUS AND SUPPLIES

As discussed in the summary section of this document, Method 28 lists specifications for wood heater installation and prescribes limits on test facility conditions, fuel properties, and wood heater operating conditions during compliance testing.* This section lists and describes the apparatus and supplies necessary to perform wood heater emission tests according to Method 28. Applicable specifications, criteria, and/or design features are given to aid in the selection of equipment that will help ensure high-quality emission data. Procedures and limits (where applicable) for equipment acceptance checks are also given.

During the procurement of equipment and supplies, a procurement log (Figure 1.1) should be used to record the descriptive title of the equipment, the identification number (if applicable), and the results of acceptance checks. If calibration is required as part of the acceptance check, the calibration data should also be recorded in a calibration log. Table 1.2, at the end of this section, is a summary of the quality assurance activities for the procurement and acceptance of apparatus and supplies.

For the purposes of this section, discussion of the procurement of apparatus and supplies is organized into eight subsections. These are as follows:

1. Apparatus and Supplies for Installation of Wood Heater and Flue Pipe;
2. Apparatus and Supplies for Process Measurements;
3. Apparatus and Supplies for Measuring Test Facility Conditions;
4. Apparatus and Supplies for Measuring Firebox Volume;
5. Test Fuel Supplies for Wood Heater Operation;
6. Apparatus for Test Fuel Storage;

---

*Method 28, Appendix A, 40 CFR 60 contains the complete requirements for Method 28 test procedures. The quality assurance procedures in this document may be used as an aid in ensuring data quality and reliability.

Item Description	Quantity	Purchase Order Number	Vendor	Date		Cost	Dispo-sition	Comments
				Ordered	Received			
Moisture Meter	1	26548	Acme Co	6/15/87	7/20/87	$325.00	Calibrated OK	Checked by J.S.

Quality Assurance Handbook

Figure 1.1. Procurement Log

7. Apparatus and Supplies for Measuring Test Fuel Specifications; and
8. Apparatus and Supplies for Test Fuel Crib Construction.

1.1 Apparatus and Supplies for Installation of Wood Heater Flue Pipe

Figure 1.2 is an example wood heater and flue pipe installation configuration that conforms to the requirements of Method 28. This figure shows both required and optional or recommended equipment. Similar wood heater and flue pipe installation configurations are used for both freestanding and fireplace insert wood-burning heaters. The wood heater and flue pipe assembly shown in Figure 1.2 or a similar configuration can be used with any of the emission sampling methods selected (i.e., Methods 5H or 5G). The components shown in Figure 1.2 are discussed in the following subsections.

1.1.1 Wood Heater Steel Flue Pipe - Method 28 requires that the steel flue pipe must extend to a height of 2.6 ± 0.15 m (8.5 ± 0.5 ft) above the scale platform. This distance should be measured from the platform on which the wood heater sits. A standard stove pipe (i.e., black wall - 24 gauge) is recommended. The steel flue pipe must be of a diameter specified by the wood heater manufacturer, usually standard 6- or 8-in. pipe. Other than single-wall steel flue pipe is allowed if specified by the manufacturer.

The flue pipe sections must fit tightly to ensure secure assembly as well as unbiased draft gauge measurements and, for Method 28A or 5H, accurate gas measurements. A high-temperature sealant and sheet metal screws are recommended for all connections.

Because wood heater heights and exhaust flange diameters may vary, an assortment of adapter sections may be necessary. Further, since some wood heater flanges may require that the adapter section be sealed with furnace cement or other sealant, the adapter sections will not always be reusable. It is recommended that the draft gauge port, which must be within 0.3 m (1 ft) of the wood heater exhaust flange, be located in the adapter section.

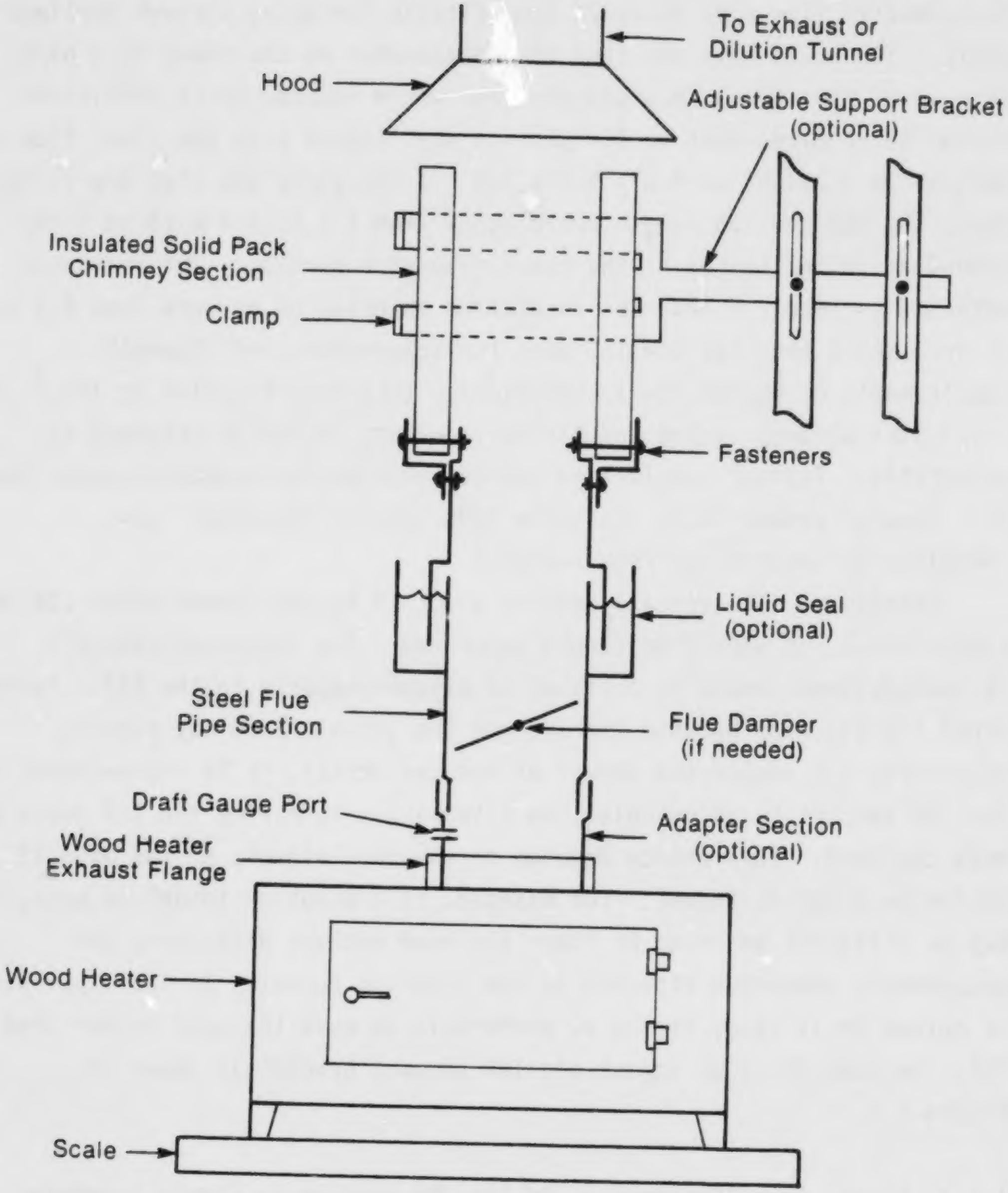

To Exhaust or
Dilution Tunnel
Hood
Adjustable Support Bracket
(optional)
Insulated Solid Pack
Chimney Section
Clamp
Fasteners
Liquid Seal
(optional)
Steel Flue
Pipe Section
Flue Damper
(if needed)
Draft Gauge Port
Adapter Section
(optional)
Wood Heater
Exhaust Flange
Wood Heater
Scale

Figure 1.2. Wood Heater and Flue Installation

1.1.2 Insulated Solid Pack Chimney - An insulated solid pack (ISP) chimney is a special flue pipe designed specifically for going through ceilings or roofs. It should have the same inside diameter as the steel flue pipe. The purpose of the ISP is to duplicate real world induced draft conditions. Method 28 requires that an ISP section must extend from the steel flue pipe section to a height of 4.8 ± 0.3 m (15 ± 1 ft) above the platform scale. Thus, the ISP section length could range from 1.5 to 2.4 m (5 to 8 ft) depending on the height of the steel flue pipe section. The reference method also requires that the insulation material be no more than 2.5 cm (1 in.) thick and that the ISP meet the temperature and strength requirements of Underwriters Laboratories (UL) specification UL 103.[6] Any solid pack chimney tested and listed according to the UL standard is acceptable. Testing and listing may be performed by companies other than UL. Several commercially available ISPs such as "Insulpak" and "Metalbestos" meet these requirements.

Because an ISP typically weighs about 15 kg per linear meter (10 lb per linear feet), it should be firmly supported. The ISP manufacturer's recommendations should be followed to attach supports to the ISP. Further, since the distance between the ISP and the exhaust hood may require adjustment (to reduce the amount of induced draft), it is recommended that the ISP support be adjustable. An alternative to moving the ISP would be to move the hood. This choice depends on the requirements of the exhaust system or dilution tunnel. For example, if a dilution tunnel is used, it may be difficult to raise or lower the hood without disturbing the measurement apparatus attached to the dilution tunnel. On the other hand, if Method 5H is used, it may be preferable to move the hood rather than the ISP. An example of an adjustable ISP support bracket is shown in Figure 1.2.

1.1.3 Liquid Seal (Optional) - If the ISP section is firmly supported as recommended in Subsection 1.1.2, a device will be required that will allow both unobstructed vertical movement of the scale platform and an airtight seal. A liquid seal (see Figures 1.2 and 1.3) is a device that serves this purpose.

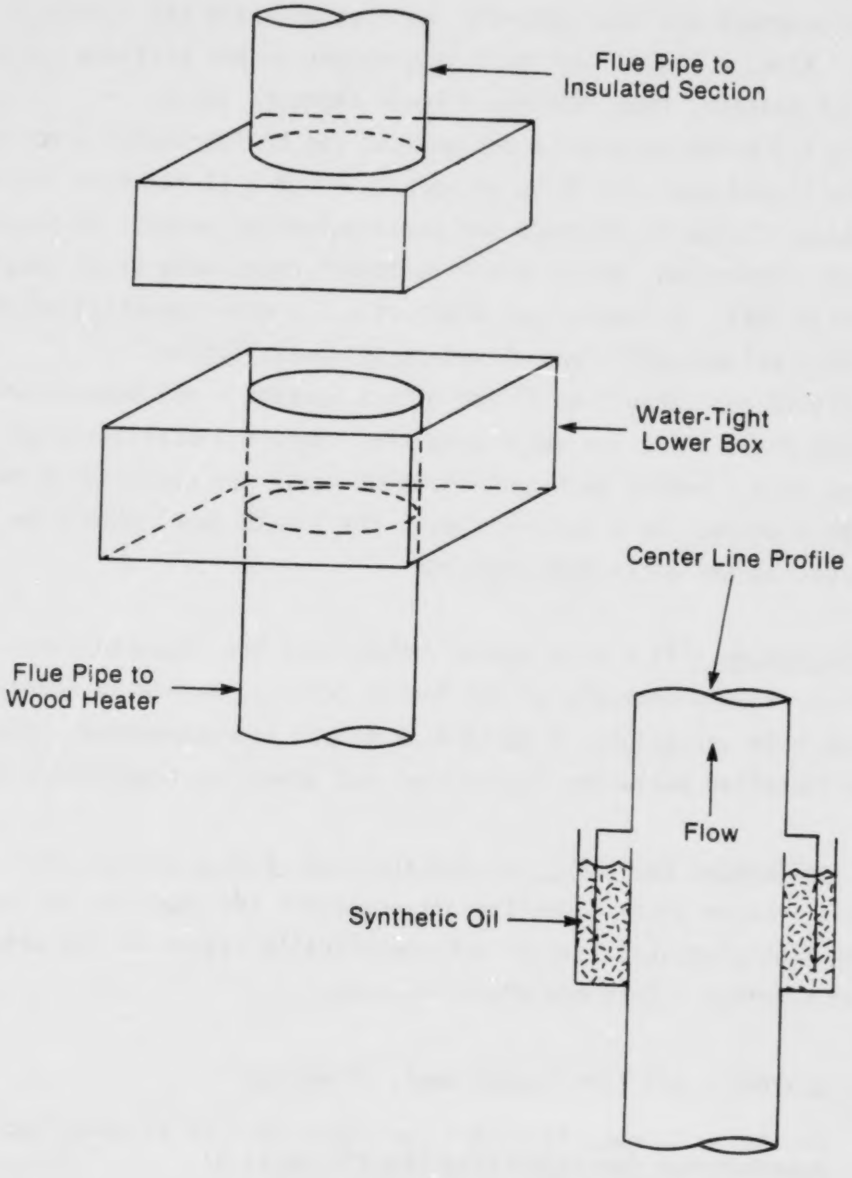

Flue Pipe to
Insulated Section
Water-Tight
Lower Box
Center Line Profile
Flue Pipe to
Wood Heater
Flow
Synthetic Oil

Figure 1.3. Liquid Seal

A liquid seal is recommended because the alternative of a freestanding steel pipe-ISP assembly could pose a safety problem if it is not firmly supported, particularly on smaller wood heaters. The liquid seal allows free scale movement and thus accurate readings with the ISP firmly supported. Also, a liquid seal puts less weight on the platform scale than does the ISP section, thus allowing a lower capacity scale.

Figure 1.3 shows an example design that can be fabricated from sheet metal. The liquid seal should be no more than 0.6 m (2 ft) from the wood heater exhaust flange to minimize the scale-supported weight, to facilitate liquid level inspection, and to minimize interference with stack sampling (e.g., Method 28A). A liquid seal depth (i.e., liquid capacity) of about 15 cm (6 in.) allows sufficient clearance for installation.

The liquid seal should be filled with a synthetic oil demonstrating a high boiling point and a low vapor pressure. Before installation of the liquid seal (i.e., before each certification test) the seal should be checked for leakage. As a further check, the liquid level should be monitored during and after each test run.

1.1.4 Flue Damper - If a wood heater cannot meet the required minimum burn rate with air supply controls at the lowest setting, Method 28 requires that a flue damper be installed. A solid disk damper is recommended. The damper should be installed below the liquid seal and above any adapter sections.

1.1.5 Miscellaneous Equipment for Installation of Wood Heater and Flue Pipe - This section lists miscellaneous equipment and supplies for wood heater and flue pipe installation not specifically listed in the preceding subsection headings. This equipment includes:

- Synthetic oil (for liquid seal, if used);
- Brackets, clamps, fasteners, or other devices as specified by the manufacturer for supporting the ISP section;
- High-temperature sealant for sealing pipe connections and sampling or measurement ports;

- Hand tools and fasteners such as drill, hammer, wood saw, hacksaw, tin snips, stove pipe crimping tool, screwdriver, wrench, sheet metal screws, and nuts and bolts as required; and
- Flue pipe adapter sections as needed.

1.2 Apparatus and Supplies for Process Measurements

Process measurements during a wood heater emission test include burn rate, flue draft, and surface and catalyst temperatures. Apparatus and supplies for performing these process measurements are discussed in this subsection.

1.2.1 Platform Scale - Method 28 requires that the platform scale have a resolution (i.e., readout graduations) as low as 0.05 kg (0.1 lb) or 1% of the test load weight, whichever is greater. The scale must also have a capacity sufficient to support the heaviest anticipated wood heater (plus test load and flue pipe assembly). It is recommended that the scale have a "tare" feature. The tare feature is an "automatic zero."

When choosing a suitable platform scale, there are several factors to consider: ease of calibration, required capacity, resolution, and temperature sensitivity. The scale manufacturer's recommended calibration procedures should be compared with the requirements listed in Section 2.0 of this manual. For example, some scales provide for a span adjustment with the tare weight set (i.e., the wood heater in place). Other scales may require that the scale be calibrated without the wood heater in place. Another important consideration in calibration is the scale's sensitivity to temperature variations. Some scales have a specified operating temperature range. These scales may require heat insulation beneath the wood heater to prevent electrical component damage and to ensure consistent calibration. Since the scale calibration should be checked at testing temperatures (e.g., during the pre-burn test), a span adjustment with the tare weight set is a highly desirable feature.

The required resolution of the platform scale is dictated by the size of the wood heater firebox. The finest resolution that will ever be required is 0.05 kg (0.1 lb). A platform scale with a resolution greater than 0.05 kg (0.1 lb) is acceptable for large fireboxes if 1% of the test fuel load is greater than 0.05 kg (0.1 lb). For example, a wood heater with a firebox volume of 2.2 ft^3, with a fuel weight of 7 lb/ft^3, would require a platform scale with a resolution of 0.15 lb (i.e., 1% of the test fuel load, 2.2 ft^3 x 7 lb/ft^3). In general, a scale with a resolution of 0.05 kg, or 0.1 lb) is recommended because it will accommodate a full range of wood heaters.

A wide variety of scale capacities and resolutions is available commercially. As examples, some platform scales with their capacities and resolutions are listed in Table 1.1. Although wood heaters up to 800 kg (1760 lb) may require testing, most wood heaters to be tested will weigh less than 454 kg (1000 lb). Note: If a platform scale with a resolution of 0.1 kg (0.2 lb) is used, a test load balance with a resolution of 0.05 kg (0.1 lb) or less should be used to measure the test load weight.

1.2.2 Draft Gauge - The reference method requires a draft gauge to measure the draft induced at the wood heater exhaust flange. The draft gauge must be able to measure negative pressure in the flue pipe at 1.25 Pa (0.005 in. H_2O). The resolution should be 0.5 Pa (0.002 in. H_2O) or less.

Micromanometers or inclined manometers, instruments for measuring small variations in pressure, can be electronic or liquid (e.g., U-type). Liquid manometers do not require calibration. Both electronic and liquid manometers will meet the required specifications. Dwyer Instruments, Inc., Fisher Scientific, and Neotronics are manufacturers of suitable manometers.

1.2.3 Wood Heater Surface Temperature Monitors - The reference method requires five temperature monitors on the wood heater surface. The temperature monitors must be accurate to within 1.5% of the absolute temperature (i.e., K or ^{o}R). Surface temperatures during emission testing usually do not exceed $400^{o}C$ ($778^{o}F$).

TABLE 1.1 EXAMPLES OF PLATFORM SCALES WITH CAPACITY AND RESOLUTION

Manufacturer[a]	Capacity	Resolution
Arlyn Scales	500 lb	0.1 lb
Arlyn Scales	1000 lb	0.2 lb
Circuits and Systems	500 lb	0.1 lb
Circuits and Systems	1000 lb	0.2 lb
Malvern Scale	600 lb	0.01 lb
Toledo Scales	1000 lb	0.1 lb
General Electronics Systems	1000 lb	0.1 lb

[a] These manufacturers are listed in the 1985 Thomas Register of American Manufacturers.[5]

Thermocouples are temperature monitoring devices that produce an electric current proportional to temperature. Several designs are capable of meeting Method 28 requirements. Considerations regarding choice of thermocouple type are: the thermocouple heat range, the method of attachment to the wood heater (must be attached to the exterior of the firebox wall and inside any air circulation jackets), reusability, and compatibility with the readout device. "Cement on" thermocouple assemblies can be easily attached to wood heater surfaces but may be hard to remove. "Bolt on" thermocouple assemblies require drilling into the wood heater but provide good thermal contact and can be removed easily. Soldered-end thermocouple wire may also be used and is less expensive than assembled thermocouples. Thermocouple installation is discussed in Section 3.2.3.

1.2.4 Catalyst Temperature Monitors - The reference method requires a temperature monitor to measure catalyst temperatures at a point 2.5 cm (1 in.) downstream from the catalyst. The temperature monitor must measure temperatures as high as 1100^{o}C (2000^{o}F) and must be accurate to within 1.5% of the absolute temperature. Another consideration is compatibility with the readout device used for the other temperature monitoring devices; all thermocouples must be of the same "type" designation if a single readout device is used. An assembled "double-protected, Type K, chromel-alumel" thermocouple is an example of a suitable monitor. These thermocouples can also be fabricated by soldering thermocouple wire.

1.2.5 Devices to Read Thermocouple Output - The readout device must be able to read temperatures in the appropriate range (18^{o}C to 1100^{o}C [64^{o}F to 2000^{o}F]) to within 1.5% of the absolute temperature. Several types of devices are available to read thermocouple outputs. These include digital thermometers, potentiometers calibrated to read temperature, and data loggers or strip chart recorders. A digital thermometer or potentiometer can be used with a selector switch to provide a readout for multiple thermocouples if the thermocouples have compatible output or are of the same "type" designation. Some recorders or data loggers may be able to handle only one thermocouple at a time.

1.2.6 Miscellaneous Equipment for Process Measurements - This section describes recommended and required equipment and supplies not listed in the preceding subsection headings.

- Calibration weights: One Class F standard weighting from 20 to 80% of the anticipated test load weight is required to check scale calibration. Five Class F weights over the span of the scale range may be required for 5-point calibration (see Section 2.1).
- A heat insulating pad to ensure that the platform scale is maintained within the temperature range specified by the manufacturer (see Figure 1.4).
- Thermocouple solder, soldering iron, drill, drill bits, high-temperature cement, nuts and bolts or screws, furnace cement or high-temperature sealant for thermocouple access holes, hole saw for thermocouple access holes.

1.3 Apparatus and Supplies for Measuring Test Facility Conditions

Method 28 requires that test facility conditions be measured and recorded before and after each certification test. This section lists and describes the necessary equipment.

1.3.1 Temperature Monitoring Device - Method 28 requires a temperature monitoring device with an accuracy of 1.5% of the absolute temperature, which corresponds to about 4.5°C (8°F) at test facility temperatures. The temperature detecting section must be at the center of a cylindrical shield 150 mm (6 in.) long and 50 mm (2 in.) in diameter.

A mercury-in-glass thermometer with its bulb at the center of the cylindrical shield is suitable for this purpose. An alternative is to use a thermocouple with the readout device used for wood heater surface temperatures. A thermocouple similar to those used for measuring wood heater surface temperatures can be used.

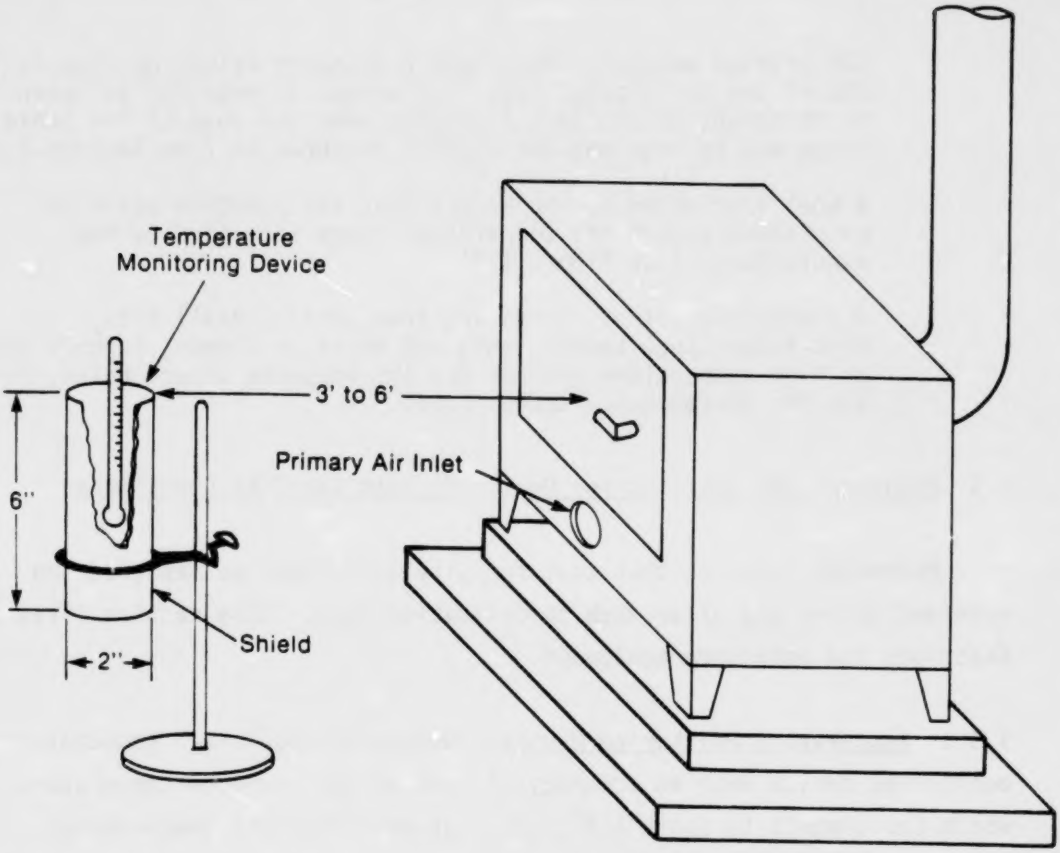

Temperature
Monitoring Device
3' to 6'
Primary Air Inlet
6"
Shield
2"

Figure 1.4. Facility Temperature Monitoring Apparatus

The cylindrical shield can be fabricated to the required dimensions from sheet metal or other suitable material. The cylinder should be of a reflective color (e.g., silver) to minimize radiant heat effects. Figure 1.4 is an example of a suitable device for monitoring facility temperature.

1.3.2 Anemometer - The reference method requires that air velocity in the vicinity of the wood heater must be less than 0.25 m/s (50 ft/min). It is recommended that the anemometer have a resolution of 0.1 m/s (20 ft/min) at this velocity.

There are two types of instruments capable of meeting these specifications: electronic anemometers (hot wire type) and vane anemometers. Electronic anemometers are available that can measure in the range from 0 to 1.5 m/s (300 ft/min) with accuracies of ±0.03 m/s (6 ft/min). Vane anemometers are generally less expensive than electronic anemometers. Vane anemometers are either swing type or propeller (revolution counting) type. The revolution counting type requires a stop watch and calculation of air velocity. Light weight hand-held swing type anemometers can be easily read at various locations. Swing type anemometers are available that measure from 0.13 to 2 ± 0.10 m/s (from 25 to 400 ± 20 ft/min).

1.3.3 Humidity Gauge - The humidity in the test facility must be measured to within 3% relative humidity. Most electronic hygrometers and wet bulb hygrometers meet this accuracy specification.

The humidity gauge can also be used to monitor wood storage room humidity, so a portable instrument is recommended. Two gauges may be desirable.

1.3.4 Barometer - The reference method requires that the air pressure in the wood heater testing area be measured to within 3.4 mbar (0.1 in. Hg) before and after each test run. If the test facility is pressure controlled (i.e., barometric chamber), the air pressure should also be recorded every 10 min during each test run.

Instruments capable of meeting these requirements include standard mercury barometers (visual readout), calibrated dial barometers, and electronic digital barometers. Some electronic digital barometers have an electronic readout for recorder or data logger attachment.

1.4. Apparatus and Supplies for Measuring Firebox Volume

Although no particular equipment is specified to measure the firebox volume, a standard tape measure can be used for most measurements. An inside caliper can be used to measure hard-to-reach areas, and a small square is useful. Also, a calculator is recommended for volume determinations.

1.5 Test Fuel Supplies for Wood Heater Operation

1.5.1 Wood Type - The reference method specifies the fuel to be used for testing. The user should verify that the lumber was properly graded. Since most structural lumber at lumber yards has already been kiln dried, a source of the proper fuel should be arranged so that an adequate supply of fuel can be obtained. The stamp, "GRN," indicates that the lumber has not been kiln dried.

1.5.2 Wood Size - The reference method requires the use of standard dimensional "four by fours" and/or "two by fours" with one by two spacers according to firebox size (actual sizes are 3 1/2 in. x 3 1/2 in., 1 1/2 in. x 3 1/2 in., and 3/4 in. x 1 1/2 in., respectively).

1.6 Apparatus for Test Fuel Storage

A separate temperature- and humidity-controlled room or enclosure for test fuel storage is recommended to provide for accurate test fuel temperature measurement and to maintain proper wood moisture content levels. The storage area temperature should be maintained within 1.5% of the absolute temperature (about 4.5^{0}C [8^{0}F]) and humidity at about 90% relative humidity.

Accurate test fuel temperature measurement is important because resistance-type moisture meter readings must be adjusted for wood temperature. Maintaining test fuel moisture content is important because if the moisture content drops below 16% wet basis (19% dry basis), the fuel may not be used for certification test runs; addition of moisture is not permitted. Therefore, the reliability of both the temperature- and the humidity-control systems in the storage area is an important factor.

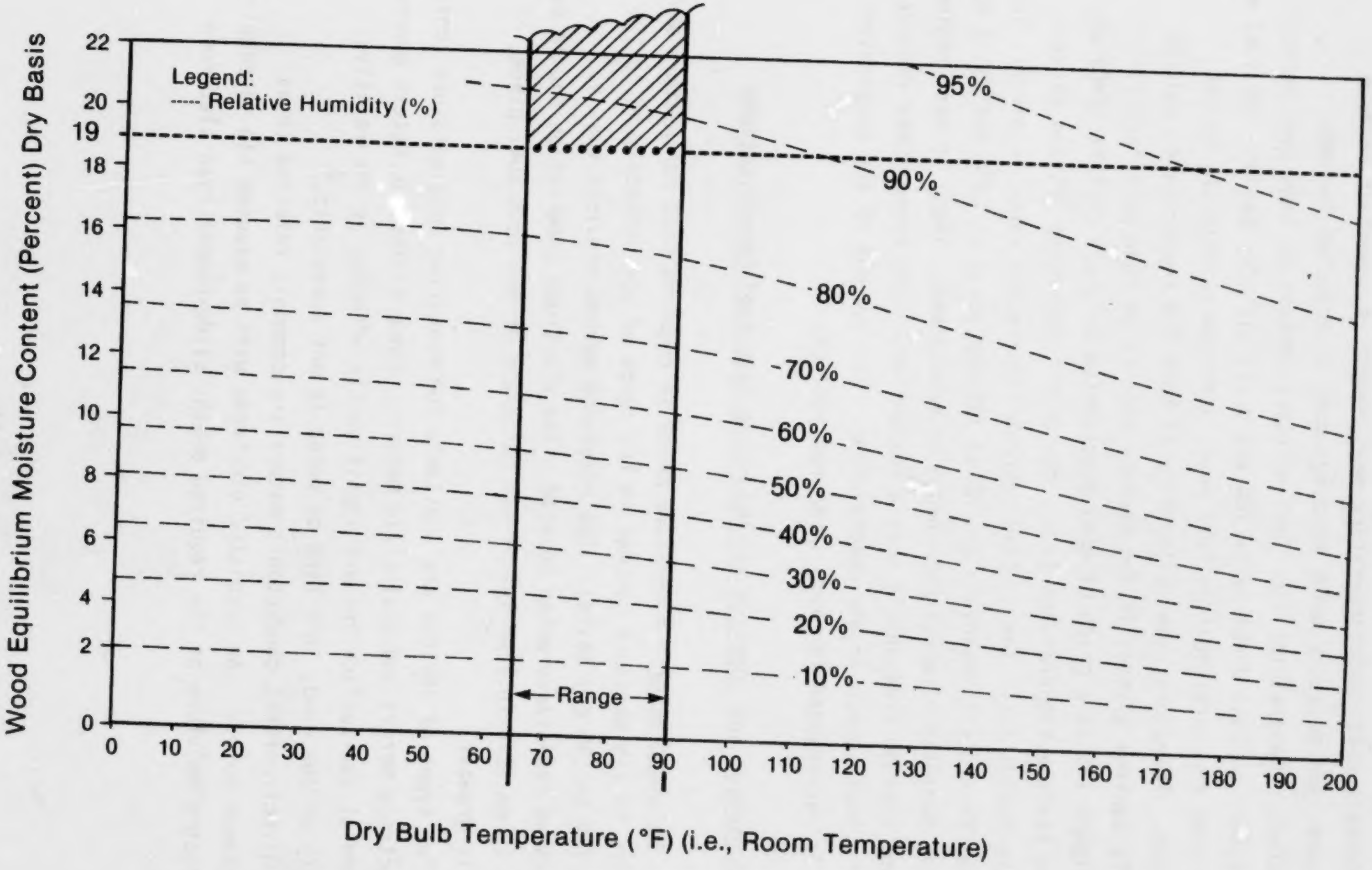
Figure 1.5 is a graph of wood equilibrium moisture content (EMC) at various storage temperatures (i.e., dry bulb temperature ^{o}F) and percent relative humidities. The desired storage temperature range is given. For example, in order to maintain an EMC of 19% dry basis at $18^{o}C$ ($64^{o}F$), a room relative humidity of about 86% should be maintained. Thus, in most regions, the wood storage area should have a humidifier. Some regions may require either a heat source or air conditioning. The low end of the temperature range is recommended for long-term wood storage.

1.7 Apparatus and Supplies for Measuring Test Fuel Specifications

1.7.1 Moisture Meter - A moisture meter is required that can measure wood moisture to ±1% moisture content in the range of approximately 16 to 20% wet basis (19 to 25% dry basis). The reference method requires that a calibrated resistance meter be used. The electrode penetration should be at least 19 mm (3/4 in.) or 1/4 of the thickness of the test fuel piece, if this is greater.

Two types of devices are available for measuring wood moisture content: conductance meters and dielectric meters. Since dielectric meters generally measure at the surface and are significantly affected by the relative density of the wood, this type of meter is not acceptable.[2]

Direct current conductance meters are commonly referred to as resistance meters. An insulated electrode with an exposed tip is required to measure moisture at the required depth; slide-hammer-type electrode



Source: U.S. Forest Products Laboratory, Madison,WI

Figure 1.5. Equilibrium Moisture Content

drivers are available to facilitate wood penetration. The resistance meter should be calibrated for Douglas fir and the type of electrode pin used. Further, some meters are adjustable for wood temperature, while others require a temperature correction factor.

1.7.2 Test Fuel Balance (Optional) - It is recommended that a scale or balance be available for test fuel weight measurement. This balance should have a resolution of 0.05 kg (0.1 lb) or better and should have sufficient capacity for the largest anticipated test load, approximately 15.9 kg (35 lb).

Electronic digital readout scales meet these specifications. Also, triple-beam, balance-type scales are suitable. In lieu of a separate scale or balance for test fuel loads, the wood heater platform scale may be used if it has a resolution of 0.05 kg (0.1 lb).

1.7.3 Fuel Temperature Monitor - The temperature of the test fuel must be determined by measuring the temperature of the area in which it has been stored for 24 h. This temperature must be maintained between 18 and 32^{o}C (64 to 90^{o}F). Since an accurate wood temperature measurement is necessary for proper wood moisture content measurement, the wood storage area temperature should remain constant for the 24-h period preceding the test crib construction. This temperature can be measured by a mercury-in-glass thermometer or by the temperature measuring device used to measure test facility temperature.

1.8 Apparatus and Supplies for Test Fuel Crib Construction

The reference method requires that uncoated, ungalvanized nails or staples be used to attach the spacers to the test fuel pieces. A cutoff saw or other similar cutting device is recommended to cut the fuel to the desired lengths. Staples and staple gun, if used, should be suitable for fastening 2-cm (3/4-in.)-thick spacers.

TABLE 1.2. ACTIVITY MATRIX: PROCUREMENT OF APPARATUS AND SUPPLIES

Apparatus	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements Are Not Met
Steel flue pipe	Diameter as specified by wood heater manufacturers; no dents or damaged flanges	Visually check upon purchase	Repair or return to supplier
Insulated solid pack chimney (ISP)	Same diameter as steel flue pipe; insulation no more than 2.5 cm (1 in.) thick; meets UL 103 requirements; no damage to insulation or flanges	Visually check upon purchase. Check with manufacturer as to UL 103 requirements	Repair or return to supplier
Liquid seal (optional)	Airtight, frictionless couple; no liquid leaks; no dents or damaged flanges	Visually check and leak test upon purchase	Repair or return to supplier
Miscellaneous:			
Synthetic oil	High boiling point; low evaporative rate	Check manufacturer's specifications	Replace with suitable material
Equipment for supporting pipe and ISP	Meets ISP manufacturer's recommendations	Check upon purchase	Replace with suitable material
High-temperature sealant	Suitable for temperature anticipated at point of use	Check specifications upon purchase; inspect upon first test run	Replace with suitable material
Hand tools and fasteners	As required	As required	Replace with suitable material

TABLE 1.2. ACTIVITY MATRIX: PROCUREMENT OF APPARATUS AND SUPPLIES (Continued)

Apparatus	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements Are Not Met
Flue pipe adapter sections	Must fit tightly and securely	Check visually upon assembly	Replace as necessary
Platform scale	Capacity for anticipated wood heaters plus flue and test fuel; resolution of 0.05 kg (0.1 lb) or 1% of test fuel weight (whichever is larger)	Upon purchase (manufacturer's certification is acceptable) and before each certification test (see Section 2.0)	Recalibrate or return to supplier
Draft gauge	Able to read 1.25 Pa (0.005 in. H_2O) with resolution of 0.5 Pa (0.002 in. H_2O)	Check for damage and calibrate upon receipt (see Section 2.0)	Adjust or return to supplier
Temperature monitors:			
Wood heater surface	Monitor temperature up to 400°C (778°F); accurate to ±1.5% absolute temperature	Check for damage and calibrate upon receipt	Repair or return to supplier
Catalyst temperature	Monitor temperature up to 1100°C (2000°F); accurate to ±1.5% absolute temperature	Check for damage and calibrate upon receipt	Repair or return to supplier
Test facility and fuel storage area	Monitor room temperature 18-30°C (64 to 90°F) accurate to ±1.5% absolute temperature	Check for damage and calibrate upon receipt	Repair or return to supplier

TABLE 1.2. ACTIVITY MATRIX: PROCUREMENT OF APPARATUS AND SUPPLIES (Continued)

Apparatus	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements Are Not Met
Miscellaneous:			
Calibration weights	Class F accuracy; 20% to 80% of anticipated test loads	Check upon receipt	Replace with suitable material
Heat insulation	Protect platform scale as required	Check upon receipt	Replace with suitable material
Tools for thermocouple installation	As required	Check upon receipt	Replace with suitable material
Anemometer	Able to read 0.25 m/s (50 ft/min) with resolution of 0.1 m/s (20 ft/min)	Visually inspect and calibrate upon receipt	Recalibrate or return to supplier
Humidity gauge	Able to read to ±3% relative humidity	Visually inspect and calibrate upon receipt	Recalibrate or return to supplier
Barometer	Resolution of 3.4 mbar (0.1 in. Hg)	Visually inspect and calibrate upon receipt	Recalibrate or return to supplier
Test fuel	Air-dried, dimensional Douglas fir; moisture content 19-25% (dry basis); grade as required in reference method.	Visually inspect and measure moisture upon receipt	Return if not proper grade; return if below 19% moisture content (dry

TABLE 1.2. ACTIVITY MATRIX: PROCUREMENT OF APPARATUS AND SUPPLIES (Continued)

Apparatus	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements Are Not Met
Test fuel (continued)			basis); accept if more than 25% moisture content (dry basis) but air-dry to acceptable level
Moisture meter	Able to read moisture content from 16-20% (wet basis) or 19-25% (dry basis) to ±1% moisture content in Douglas fir at depth up to 2.5 cm (1 in.)	Visually inspect and calibrate upon receipt	Recalibrate or return to supplier
Wood storage area	Able to maintain temperature to ±1.5% absolute between 18 and 32°C (64 and 90°F) for 24 h; able to control humidity to maintain fuel moisture content	On construction and as required	Replace or repair
Apparatus and supplies for test fuel crib construction	As required	Upon purchase	Replace

2.0 CALIBRATION OF APPARATUS

Calibration of apparatus is an important factor in maintaining data quality. This section describes the calibration procedures for the equipment described in the previous section. To facilitate reporting, a log book of all calibrations should be maintained that includes a calibration log for each piece of equipment. Further, a calibration summary sheet should be submitted with each certification test report. Blank calibration sheets are provided in Section 11.0 for the convenience of the user. Table 2.1, at the end of this section, summarizes the quality assurance activities for calibration.

2.1 Platform Scale and Monitor

2.1.1 Frequency and Specifications of Calibration - Method 28 specifies that before the first certification test (or upon purchase), the platform scale must be calibrated with five calibration weights spanning the operational range of the scale. For this initial calibration of a new scale, the manufacturer's calibration certification is acceptable.

Before each subsequent certification test, a single-point calibration check must be made with a Class F calibration weight that is between 20 and 80% of the test load weight. It is recommended that this calibration check also be performed before each individual test run. If the scale cannot reproduce the certified Class F weight to within 0.05 kg (0.1 lb), then the scale must be recalibrated with a five-point calibration according to the manufacturer's instructions.

2.1.2 Method of Calibration - Different scales require different methods of calibration. The scale manufacturer's instructions should be followed closely. This subsection gives the general procedure required by Method 28.

Before beginning the single-point calibration check required before the certification test, the wood heater with flue pipe and liquid seal (if used) should be assembled for testing. The scale should then be "tared" (i.e., set to zero reading). For scales without a tare feature, the weight of the wood heater assembly should be recorded before each subsequent single-point calibration check in case the weight reading has drifted. The Class F calibration weight should then be placed centrally on the scale. This weight reading (or weight difference) should be within 0.05 kg (0.1 lb) of the certified weight.

If the scale does not have a resolution small enough to verify this tolerance, the Class F weight must be reproduced to within 0.00 kg (lb). For example, if a 10.0-lb Class F weight standard is used to calibrate a scale with a resolution of 0.1 lb, the scale reading can be either 9.9 lb, 10.0 lb, or 10.1 lb and still be acceptable. However, if a scale with a resolution of 0.2 lb is used, the scale must read exactly 10.0 lb for a 10.0 lb Class F weight standard; 9.8 lb or 10.2 lb is not acceptable.

Some scales provide for a span adjustment with the tare weight (i.e., wood heater) in place. For these scales, if the Class F weight is not reproduced to within the allowed tolerance, the span should be readjusted and the tare reset according to the manufacturer's instructions. The scale should then be checked with the Class F weight. If the scale reading is then within the allowed tolerances, the single-point pretest calibration check requirement has been met.

If this single-point calibration check cannot be met within the allowed tolerance with a tare-in-place span adjustment, then the scale must be recalibrated by using five test weights spanning the operational range of the scale. The scale manufacturer's recommendations should be followed. In lieu of purchasing certified Class F calibration weights for full-scale calibrations, various companies offer scale calibration and maintenance services.

The platform scale should be tared before each individual test run, as well as before each certification test, because some scales may experience a change in tare "memory" after several days if a heavy weight (e.g., wood heater) is left in place. The span check (i.e., single-point calibration) is also recommended at this time to help ensure good data quality. A post-test calibration check after the final test run is also recommended.

Temperature can affect platform scale calibration so the calibration should be checked at the operating temperatures expected during the emission test. The pretest burn is an appropriate time to perform this calibration check. An insulated pad between the platform scale and the wood heater can help stabilize the platform scale temperature. For scales that have a designated temperature operating range, a temperature monitor should be placed on the platform to determine if the operating temperature has been exceeded.

All calibration checks and adjustments should be recorded on a calibration sheet such as that shown in Figure 2.1. This information should also accompany each certification summary sheet (see Figure 2.5). Blank forms are supplied in Section 11.0 for this purpose.

2.2 Test Fuel Balance

2.2.1 Frequency and Specifications of Calibration - The balance must be calibrated upon purchase and before each certification test. Calibration should be checked to ±0.05 kg (0.1 lb).

2.2.2 Method of Calibration - Calibration should be checked with a Class F calibration standard weighing between 20 and 80% of the test load weight. The balance manufacturer's recommendations should be followed for calibration adjustments. Following adjustments, recheck the balance weight readings with the Class F weight. Record all calibration checks and adjustments on a calibration sheet such as that shown in Figure 2.1. This information should also be included on a calibration summary sheet to be submitted with each certification test report.

2.3 Temperature Monitors

2.3.1 Frequency and Specifications of Calibration - The temperature monitors must be checked for calibration before the first certification test (or upon purchase) and semiannually thereafter. All temperature monitoring devices should reproduce reference temperatures to within 1.5% of the absolute temperature (i.e., K or ^{o}R).

Scale Model: Platform Weighall-2000
Balance

Wood Heater Model AJAX LONGBURN
Weight of Test Fuel 25 lbs

Test Facility Firstime Testers
Calibration Performed By J. Doe
Date 7/30/87

Time	Test Run Number	Platform Temperature	Class F Calibration Weight (A)	Initial Scale Reading or Tare (B)	Final Scale Reading (C)	Measured Calibration Weight (D = C – B)	Difference (D minus A)	Action Taken
8:00 AM	# 2	87°F	10.0 lbs	539.8lb	549.7	9.9	– 0.1lb	none (OK)

Figure 2.1. Scale Calibration Sheet

2.3.2 Calibration Procedures - The calibration procedure used for temperature monitors depends on the temperature range of the monitor. Sensing devices for measuring temperatures up to 405°C (761°F) (i.e., wood heater surface and room temperature monitors) should be calibrated against a mercury-in-glass thermometer which meets ASTM E-1 No. 63C or 63F specifications. Alternatively, a reference thermocouple and potentiometer certified by the National Bureau of Standards (NBS) or thermometric fixed points may be used. For sensing devices for measuring temperatures over 405°C (761°F) (i.e., the probe for catalyst temperature), an NBS-calibrated reference thermocouple and potentiometer should be used. The following paragraphs describe these procedures.

The thermometric fixed-point reference method can be used with or without an ASTM mercury-in-glass reference thermometer. With an ASTM thermometer, the reference thermometer should be compared with the temperature sensor at two points. For room temperature sensors, room temperature and a water-ice bath are suitable points. For wood heater surface temperature monitors, room temperature and boiling water are suitable points. A liquid with a high boiling point such as cooking oil can be substituted for water to more closely approximate wood heater surface temperatures. The reference thermometer and the temperature sensor should agree to within 1.5% of the absolute temperature at each point. Figure 2.2A is an example of a calibration sheet using an ASTM reference thermometer.

Without an ASTM thermometer, a water-ice bath (i.e., 0°C or 32°F) and boiling water may be used as the two reference temperatures. However, deionized water should be used for the ice bath, and the boiling water temperature must be adjusted for barometric pressure. See Figure 2.2B for an example of this adjustment. The temperature sensor should agree with both fixed points to within 1.5% of the absolute temperature.

Figure 2.2C is an example of a catalyst temperature monitor calibration check. A reference thermocouple and potentiometer or the equivalent must be used for this calibration. In this case, flue temperature is used as a heat source. Other heat sources such as a kiln are acceptable.

Temperature Monitor Type Thermocouple
Identification Number TC-1

Reference Temperature Monitor Type ASTM mercury
Identification Number ASTM 63

Readout Device Meter #10

Test Facility First time Testers
Calibration Performed By Bill Smith
Date 7-20-87

Ambient Temperature 75°F
Barometric Pressure 29.50

Reference Point Source [1]	Temperature of Reference Point [2]	Observed Temperature		Difference in Percent of Absolute Temperature [3]	Action Taken
		A Reference Temperature Monitor	B Temperature Monitor		
ice + water	32°F	32°F	30°F	0.4%	OK
boiling water	212°F	211°F	195°F	2.3%	Replace Wire
"	"	211°F	209°F	0.3%	OK

[1] Reference Points include ice-bath, boiling water, furnace, etc.

[2] Boiling Point H_2O in °C = 100 – .94 (29.92 – Barometric Pressure in in. Hg)
Boiling Point H_2O in °F = 212 – 1.69 (29.92 – Barometric Pressure in in. Hg)

[3] Difference in Percent Absolute = $\left(\frac{A - B}{A + 273}\right) \times 100$ for A and B in °C; $\left(\frac{A - B}{A + 460}\right) \times 100$, for A and B in °F

Figure 2.2A. Temperature Monitor Calibration Sheet

Temperature Monitor Type Thermocouple
Identification Number TC #3

Reference Temperature Monitor Type NA
Identification Number ____________

Readout Device Meter #10

Test Facility First time Testers
Calibration Performed By Bill Smith
Date 7-21-87

Ambient Temperature 70 °F
Barometric Pressure 28.10

Reference Point Source [1]	Temperature of Reference Point [2]	Observed Temperature		Difference in Percent of Absolute Temperature [3]	Action Taken
		A Reference Temperature Monitor	B Temperature Monitor		
Ice + Water	32°F →	32°F	28°F	0.8%	OK
boiling water	208.9°F →	208.9°F	190°F	2.8%	replace TC
" "	"	"	(TC#1) 192°F	2.6%	adjust meter span
" "	"	"	209°F	0.0%	TC-3 OK
ice + water	32°F →	32°F	33°F	0.2%	TC #3 OK for use

[1] Reference Points include ice-bath, boiling water, furnace, etc.

[2] Boiling Point H_2O in °C = 100 − .94 (29.92 − Barometric Pressure in in. Hg)
Boiling Point H_2O in °F = 212 − 1.69 (29.92 − Barometric Pressure in in. Hg)

[3] Difference in Percent Absolute $= \left(\frac{A - B}{A + 273}\right) \times 100$ for A and B in °C; $\left(\frac{A - B}{A + 460}\right) \times 100$, for A and B in °F

Figure 2.2B. Temperature Monitor Calibration Sheet

Temperature Monitor Type Thermocouple
Identification Number TC # 6

Reference Temperature Monitor Type ASTM ref. TC
Identification Number ASTM # 5

Readout Device Meter # 10

Test Facility Firstime Testers
Calibration Performed By Bill Smith
Date 7-20-87

Ambient Temperature 75 °F
Barometric Pressure 29.50

Reference Point Source [1]	Temperature of Reference Point [2]	Observed Temperature		Difference in Percent of Absolute Temperature [3]	Action Taken
		A Reference Temperature Monitor	B Temperature Monitor		
reference TC + potentiometer	1000 °F	1000 °F	990 °F	0.6%	OK for use

[1] Reference Points include ice-bath, boiling water, furnace, etc.

[2] Boiling Point H_2O in °C = 100 – .94 (29.92 – Barometric Pressure in in. Hg)
Boiling Point H_2O in °F = 212 – 1.69 (29.92 – Barometric Pressure in in. Hg)

[3] Difference in Percent Absolute = $\left(\frac{A - B}{A + 273}\right) \times 100$ for A and B in °C; $\left(\frac{A - B}{A + 460}\right) \times 100$, for A and B in °F

Figure 2.2C. Temperature Monitor Calibration Sheet

During documentation of calibration data, each temperature sensing device should be numbered and that number recorded on a calibration sheet. The readout device should also be numbered and that number recorded on this data form. Since both the sensor and the readout device are potential sources of error, care must be taken to determine the accuracy of each. Figure 2.2B shows how to carry out this procedure. Thermocouples should be repaired or replaced if they are out of specification. Digital thermometers and other readout devices should be adjusted according to the manufacturer's instructions.

All measurements and actions taken should be recorded semiannually on a calibration sheet. A separate calibration sheet should be prepared for each temperature monitor, and a record of these calibrations should be submitted with the certification test report on a summary sheet as in Figure 2.5.

2.4 Anemometer

2.4.1 Frequency and Specifications of Calibration - The anemometer should be calibrated as necessary according to the manufacturer's instructions. The anemometer should be capable of measuring velocities less than ±0.1 m/s (20 ft/min).

2.4.2 Method of Calibration - Anemometers can be calibrated by either of two methods in accordance with EPA Method 14, Section 4.1.1: (1) direct calibration by comparison with an NBS-traceable anemometer or (2) calibration by direct measurement (e.g., by moving the anemometer through still air at a measured rate of speed and recording the output). It is recommended that the calibration be checked at 0.25 m/s (50 ft/min) and at the lowest measurable anemometer response or threshold level. This threshold level must be less than 0.25 m/s (50 ft/min).

For propeller-type anemometers, the threshold torque (force required to turn a stationary propeller) should be less than that corresponding to a velocity of 0.25 m/s (50 ft/min). One should make sure that the propeller is not stuck by spinning it manually before calibration and use. The calibration should be recorded semiannually on a form such as that shown in

Figure 2.3A. Record of this calibration should be submitted with the certification test report on a summary sheet such as that shown in Figure 2.5.

2.5 Barometer

2.5.1 Frequency and Specifications of Calibration - The barometer should be calibrated before the first certification test and semiannually thereafter. The barometer should be accurate to within 2.5 mm Hg (0.1 in. Hg). Mercury-in-glass barometers need not be calibrated, but should be checked for damage.

2.5.2 Method of Calibration - The barometer should be calibrated against a mercury-in-glass barometer or the equivalent. In lieu of this, the absolute barometric pressure may be obtained from a nearby National Weather Service (NWS) station. Usually, the NWS value is already adjusted to sea level. This value must be corrected to the absolute barometric pressure at the testing facility elevation. After determining if the NWS value has been adjusted for sea level, the procedure is either to subtract 2.5 mm Hg/30 m (0.1 in. Hg/100 ft) from the station value for an elevation increase or add 2.5 mm Hg/30 m (0.1 in. Hg/100 ft) for an elevation decrease. If the barometer cannot be adjusted to agree to within 2.5 mm Hg (0.1 in. Hg) of the reference barometric pressure, it should be returned to the manufacturer or replaced. Semiannually, a record of all measurements and corrective actions taken should be made on a calibration sheet such as that shown in Figure 2.3B. This calibration sheet and a summary sheet such as that shown in Figure 2.5 should be submitted with each certification test report.

2.6 Draft Gauge

2.6.1 Frequency and Specifications of Calibration - The draft gauge should be calibrated according to the manufacturer's instructions. The gauge should be accurate to ±0.5 Pa (0.002 in. H_2O) at 1.25 Pa (0.005 in. H_2O). The calibration should be checked in the range from 1.25 to 25 Pa (0.005 to 0.10 in. H_2O).

Instrument to be Calibrated Anemometer
Model Number Weathervane One

Test Facility Firstime Testers
Calibration Performed By JS Doe
Date of Calibration 7/15/87

Method of Measurement	Reference Value (A)	Measured Value (B)	Difference (A minus B)	Acceptable Tolerance	Action Taken
Walk – 25 feet 30 sec	50 fpm	41 fpm	9 fpm	± 20 fpm	OK
25 ft in 21 sec	71.4 fpm	60 fpm	11.4 fpm	"	
25 ft in 43 sec	34.8 fpm	0	34.8 fpm	"	oil bearings
25 ft in 42 sec	35.7 fpm	32 fpm	3.7 fpm		OK for use

Figure 2.3A. Semiannual Calibration Sheet

Instrument to be Calibrated Barometer
Model Number Acme 2000 A

Test Facility Firstime Testers
Calibration Performed By John Doe
Date of Calibration 7/15/87

Method of Measurement	Reference Value (A)	Measured Value (B)	Difference (A minus B)	Acceptable Tolerance	Action Taken
mercury barometer	28.73 in Hg	28.78 in. Hg	-0.05 in Hg	± 0.1 in Hg	OK

Figure 2.3B. Semiannual Calibration Sheet

2.6.2 Method of Calibration - Electronic manometers should be calibrated against a liquid manometer and adjusted according to the manufacturer's instructions. Liquid manometers do not require calibration. They should, however, be checked for proper liquid level. The calibration data should be recorded on a form such as that shown in Figure 2.3C. This calibration sheet and a summary sheet such as that shown in Figure 2.5 should be submitted with each certification test report.

2.7 Humidity Gauge

2.7.1 Frequency and Specifications of Calibration - The humidity gauge should be calibrated according to the manufacturer's instructions. The gauge should be accurate to ±3% relative humidity.

2.7.2 Method of Calibration - Humidity gauges should be calibrated according to the manufacturer's instructions. The calibration data should be recorded on a form such as that shown in Figure 2.3D. This calibration sheet and a summary sheet such as Figure 2.5 should be submitted with each certification test report.

2.8 Wood Moisture Meter

2.8.1 Frequency and Specifications of Calibration - Since wood moisture measurement directly affects the burn rate determination, the wood moisture meter must be calibrated before each certification test. Ideally, the meter should be calibrated each time it is used to measure the test fuel moisture. The meter should be accurate to ±1% moisture reading.

2.8.2 Method of Calibration - A resistance-type meter should be calibrated against known resistances according to the manufacturer's specifications. The resistances should be set for Douglas fir and for the type of electrode pins used. Before calibration, the electrode insulation should be checked for breaks. Insulation breaks will bias a reading to the highest moisture

Instrument to be Calibrated Draft Gauge
Model Number Micro 500M

Test Facility Firstime Testers
Calibration Performed By U.S. Doe
Date of Calibration 7/15/87

Method of Measurement	Reference Value (A)	Measured Value (B)	Difference (A minus B)	Acceptable Tolerance	Action Taken
against Liquid manometer	0.009 in. H_2O	0.010 in. H_2O	– 0.001	± .002 in. H_2O	need lower draft
"	0.005 in. H_2O	0.007 in. H_2O	– 0.002	"	OK for use

Figure 2.3C. Semiannual Calibration Sheet

Instrument to be Calibrated Humidity Gauge
Model Number Acme

Test Facility Firstime Testers
Calibration Performed By J. S Doe
Date of Calibration 7/15/87

Method of Measurement	Reference Value (A)	Measured Value (B)	Difference (A minus B)	Acceptable Tolerance	Action Taken
check against NBS hygrometer	90% Rel. Hum	88% Rel Hum	2% Rel Hum.	± 3% Relative Humidity	OK for use

Figure 2.3D. Semiannual Calibration Sheet

if a moisture gradient exists in a wood sample. Electrodes should be visibly clean. The temperature of the moisture meter should be allowed to equilibrate to the approximate fuel temperature.

At least two resistances should be used to calibrate the meter. Resistances corresponding to 19 and 22% moisture content (dry basis) are recommended. The calibration should not be extrapolated below the lowest value (i.e., the lowest value resistance should correspond to no more than 19% moisture content [dry basis] or 16% [wet basis]). Extrapolation above 21% moisture content (dry basis) is allowed if a resistance corresponding to 21% or more is used. Moisture level readings greater than 25 to 27% moisture content (dry basis) cannot be measured with confidence. The calibration data should be recorded on a form such as Figure 2.4 and reported in the certification test report on a summary sheet such as Figure 2.5.

2.8.3 Oven-Drying Method - The oven-drying method is the universally accepted method for determining moisture content in wood-seasoning operations such as air drying. Since oven drying is a destructive process (i.e., the wood tested cannot later be used as a test fuel), it is of use only to check the accuracy of wood moisture measurement methods.

The procedure is as follows:

1. Cut representative samples of the test fuel and measure with the resistance meter according to Method 28 (i.e., on three sides). Record the temperature of the test fuel and adjust moisture content reading if necessary.
2. Weigh on a balance to an accuracy of ±0.2% sample weight.
3. Heat in an oven at 103 ± 2^oC (217 ± 4^oF) until weight changes less than 0.2% of the original sample weight in a 2-h period. Avoid drying longer than necessary.
4. Calculate moisture content as follows:

percent (dry basis) = [(A - B)/B] x 100
where A = original weight
B = oven-dry weight

Moisture Meter Type Resistance - slide hammer
Model Name Wetwood 200
Model Number 6DF-2A
Operating Temperature 70°F

Test Facility Firstime Testers
Calibration Performed By J. O. Doe
Date of Calibration 7/30/87

Reference Source	Moisture Content Equivalent of Reference Source (A)	Moisture Meter Reading (B)	Difference (Should be Within ± 1%) (A minus B)	Action Taken
Resistance Bar #1	22% MC @ 70°F	20% MC	2% MC	replace battery
"	"	22.5% MC	- 0.5% MC	OK
Bar #2	19% MC @ 70°F	19.5% MC	- 0.5% MC	OK for use

Figure 2.4. Moisture Meter Calibration Sheet

Instrument Calibrated/ Identification Number	Date of Calibration	Reference Used	Reference Value	Measured Value	Difference	Acceptable Tolerance
Platform Scale	7-30-87	Class F Std.	10.0 lbs	9.9 lb	0.1 lb	± 0.05 kg (0.1 lb)
Test Fuel Balance	not used					± 0.05 kg (0.1 lb)
Moisture Meter	7-30-87	Resistance Bar	22% MC 19% MC	22.5% MC 19.5% MC	0.5% 0.5%	±1% Moisture Content
Temperature Monitors						± 1.5% Absolute Temperature (°K or °R)
Thermocouple 1	7-20-87	mercury in glass	211° F	209°F	0.3%	
Thermocouple 2	7-20-87	" " "	211°F	213°F	0.3%	
Thermocouple 3	7-20-87	fixed point	211.3 °F	210 °F	0.2%	
Thermocouple 4	7-20-87	" "	211.3°F	205°F	0.9%	
Thermocouple 5	7-20-87	" "	211.3 °F	215°F	0.6%	
Thermocouple 6	7-21-87	reference TC + potentiometer	1000° F	990°F	0.6%	
Thermocouple 7		not used				
Readout Device						
Draft Gauge	7-15-87	liquid manometer	0.005 in H_2O	0.007 in H_2O		0.5 Pa (0.002 in. H_2O)
Anemometer	7-15-87	time walk	35.7 fpm	32 fpm		± 0.1 m/sec (20 ft/min)
Barometer	7-15-87	mercury barometer	28.73 in Hg	28.78 in Hg		± 2.5 mm Hg (0.1 in Hg)
Humidity Gauge	7-15-87	NBS hygrometer	90% RH	88% RH		± 3% Relative Humidity

Figure 2.5. Summary Sheet: Instrument Calibration

5. Compare this value with the moisture content (dry basis) determined by the moisture meter. If necessary, calibrate the moisture meter and recheck with the calibration resistance. Note the corrected resistance/moisture relationship for future calibration checks.

TABLE 2.1. ACTIVITY MATRIX: CALIBRATION OF APPARATUS

Apparatus	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements Are Not Met
Platform scale	±0.05 kg (0.1 lb)	Before first certification test (manufacturer's calibration is acceptable for initial calibration) and before each subsequent certification test - Class F weight	Five-point recalibration
Balance (optional)	±0.05 kg (0.1 lb)	Before each certification test - Class F weight	Recalibrate
Temperature monitors	±1.5% absolute temperature	Before first test and semiannually - ASTM thermometer or Method 2	Replace or adjust
Anemometer	±0.1 m/s (20 ft/min) at 0.25 m/s (50 ft/min)	Before first test and semiannually - manufacturer's instructions	Replace or adjust
Barometer	±0.1 in. Hg	Before first test and semiannually - mercury barometer	Replace or adjust
Draft gauge	±0.5 Pa (0.002 in. H_2O) at 1.25 Pa (0.005 in. H_2O)	According to manufacturer's instructions - liquid manometer	Replace or adjust
Humidity gauge	±3% relative humidity	According to manufacturer's instructions - wet bulb hygrometer	Replace or adjust

TABLE 2.1. ACTIVITY MATRIX: CALIBRATION OF APPARATUS (Continued)

Apparatus	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements Are Not Met
Wood moisture meter	±1% at 19% to 25% moisture (dry basis)	Before each certification test - resistance method	Replace or adjust

3.0 PRETEST PROCEDURES

For the purposes of this section, discussion of pretest procedures is organized into nine activity categories. These are as follows:

- Measurement of firebox volume,
- Wood heater installation,
- Apparatus check and calibration,
- Catalytic combustor and wood heater aging,
- Secondary air validation procedure,
- Test fuel measurements,
- Test fuel crib construction,
- Pretest facility condition measurements, and
- Pretest burn conditions.

An activity matrix summarizing quality assurance activities for pretest procedures is presented in Table 3.2 at the end of this section. Figure 3.18 at the end of this section is a checklist to assist testing personnel in conducting pretest procedures.

3.1 Measurement of Usable Firebox Volume

Detailed measurement of the firebox dimensions is required to calculate usable firebox volume. The usable firebox volume determines the mass of fuel to use during emission testing. It is recommended that the firebox measurements be made upon receipt of the heater, prior to installing it for testing or aging purposes. Since the calculation of usable firebox volume is a critical determination and subject to error, at least two independent determinations should be performed prior to emission testing. Agreement of the independent volume determinations to within 5% is recommended.

3.1.1 Firebox Volume Measurement Definitions - Method 28 specifies guidelines to be followed when making volume measurements. Definitions for height, length, and width are as follows:

1. Height - The vertical distance extending above the loading door, if fuel could reasonably occupy that space, but not more than 0.05 m (2 in.) above the peak height of the loading door, to the floor of the firebox (i.e., below a grate) if the grate allows a 0.025 m (1 in.) diameter piece of wood to pass through the grate, or, if not, to the top of the grate. Firebox height is not necessarily uniform but must account for variations caused by internal baffles, air channels, or other permanent obstructions.

2. Length - The longest horizontal fire chamber dimension that is parallel to a wall of the chamber.

3. Width - The shortest horizontal fire chamber dimension that is parallel to a wall of the chamber.

3.1.2 Firebox Volume Adjustments - Areas inside the firebox where wood cannot reasonably be placed are allowed to be excluded from the usable volume determination. Examples of specific adjustments to firebox volume measurements required and/or allowed by Method 28 are summarized below:

1. Volume determinations should be adjusted to exclude space occupied by firebrick or permanent fixtures.

2. Width and length dimensions should be measured above the firebrick lining and extend to the firebox walls, if the firebrick on the walls extends less than one-third of the usable height.

3. Width and length dimensions should be measured to the firebrick, if the firebrick extends more than one-third of the usable height.

4. Areas around the permanent log retainers or grates should be excluded from usable volume determinations, if the manufacturer recommends that wood should be placed only on the retainers or grates and the log retainer or grate is a permanent fixture.

5. Areas adjacent to and above a baffle (up to 0.05 m, or 2 in., above the fuel loading opening) should be included if 0.10 m (4 in.) or more horizontal space exists between the edge of the baffle and a vertical obstruction (e.g., sidewalls or air channels).

6. Areas above an ash lip should be excluded from the usable volume measurements unless these areas make up more than 10% of the usable firebox volume that does not include the area above the ash lip.

7. If the criterion in Item 6 is not met, areas above the ash lip should be included if testing personnel judge that consumer loading practices would generally use such space. For instance, if fuel is to be loaded front to back, an ash lip may be considered usable firebox volume.

Figure 3.1 is a general example illustrating areas within a firebox that should be excluded when determining usable firebox volume.

3.1.3 Firebox Volume Calculations and Documentation - Firebox volume determinations must be documented and submitted with a certification test report. The following step-by-step procedure should be used as a guideline for determining the firebox volume. Using a standard set of procedures such as these will help the testing team obtain accurate measurements and results that can be reproduced by the auditor.

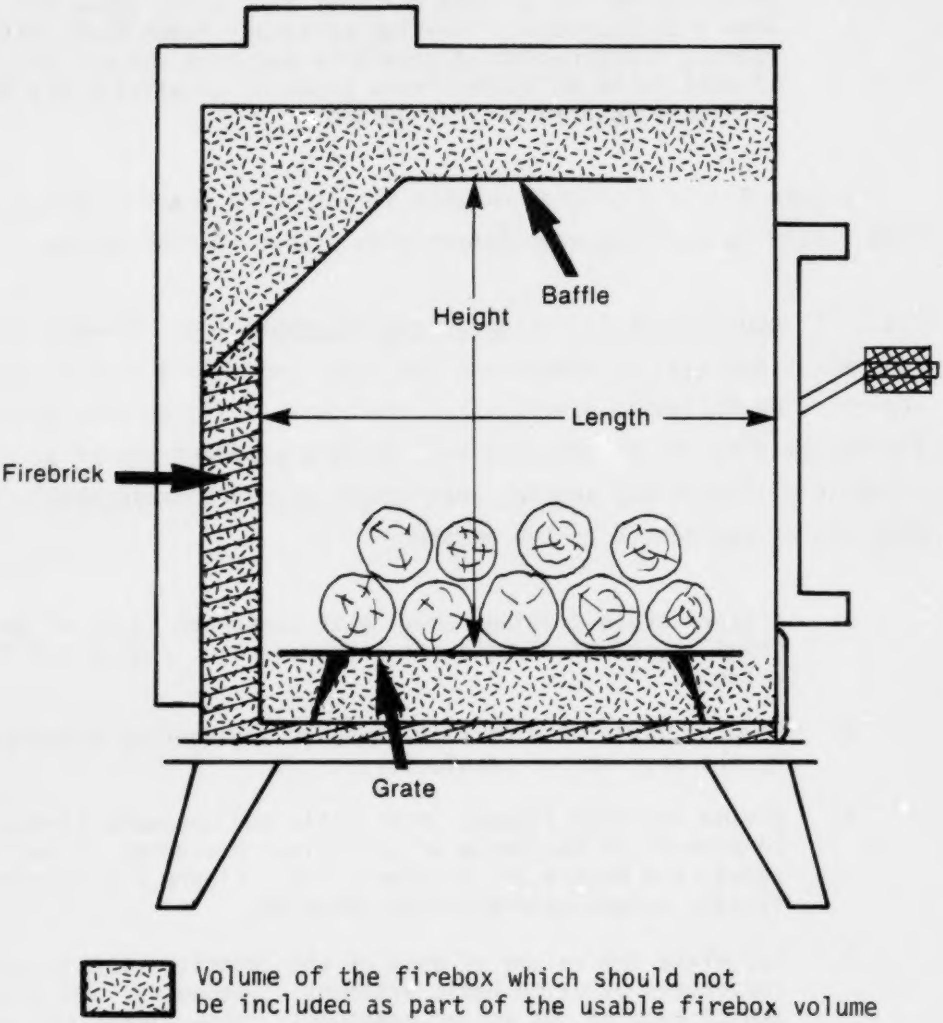
1. Prepare scale drawings showing at least two views of the firebox, detailing critical interior measurements. Figure 3.2 is a general example.

2. Compare measured dimensions against engineering drawings provided by the wood heater manufacturer.

3. Divide interior firebox into usable and unusable firebox volume components on the basis of guidelines presented in Section 3.1.2, above, and Method 28, Section 6.2.4. Figure 3.3 illustrates this firebox volume determination approach.

4. Calculate the volume of each of the interior firebox volume components by using basic arithmetic, geometry, and trigonometry. Sketch each of the volume components, show dimensions and calculations, and provide rationale for including or excluding each component as usable volume. Figure 3.4 is an example of this step.

5. Calculate usable firebox volume by summing all usable component volumes as calculated in Step 4. Confirm the calculated usable volume by subtracting the sum of the unusable volume components from the total interior firebox volume (see Figure 3.4).


Baffle
Height
Length
Firebrick
Grate

▨ Volume of the firebox which should not be included as part of the usable firebox volume

Figure 3.1 Example of Usable Firebox Volume

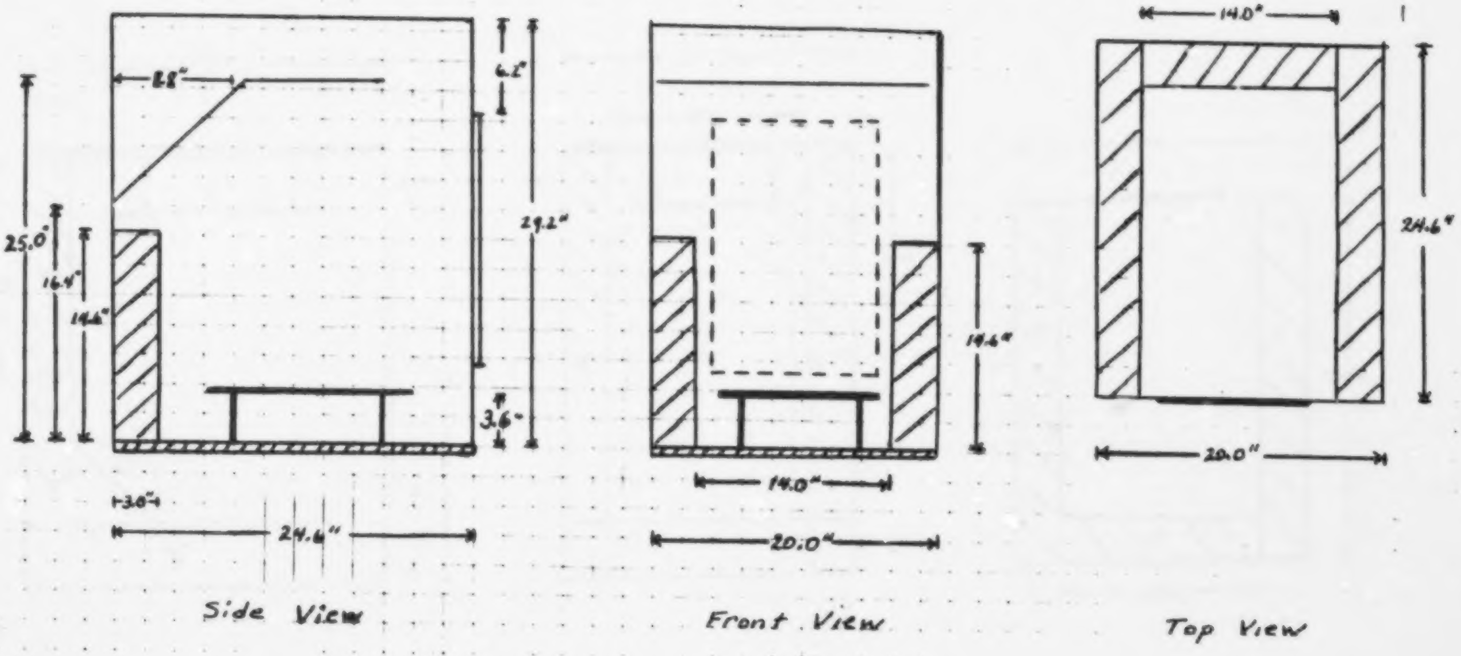

8.8"
6.2"
29.2"
3.6"
25.0"
16.4"
14.4"
3.0"
24.6"
Side View
14.4"
14.0"
20.0"
Front View
14.0"
24.6"
20.0"
Top View

Figure 3.2. Example of Scale Firebox Drawings to Document Usable Volume Determinations

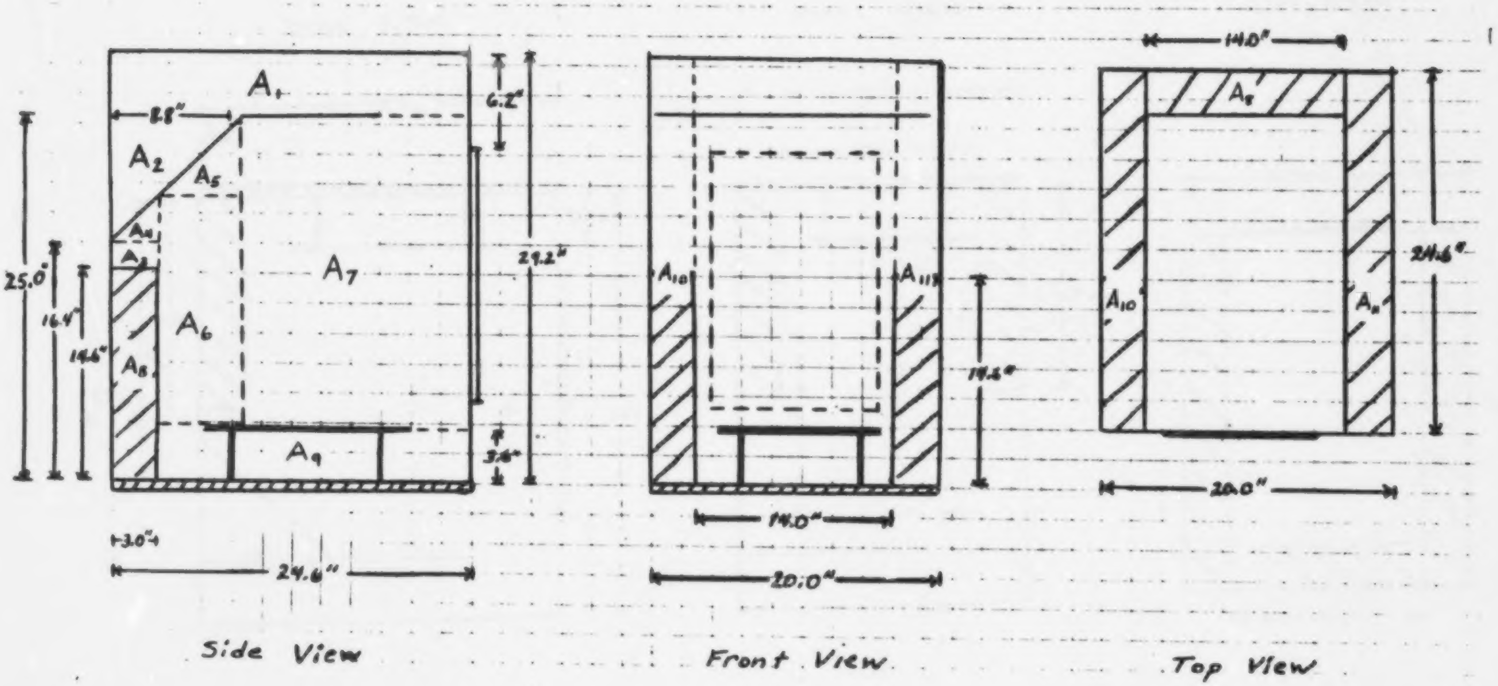
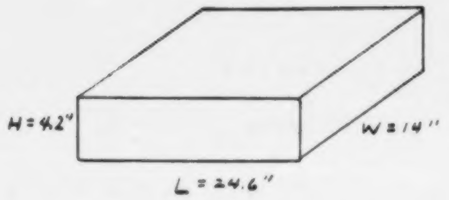

A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
A8
8.8"
6.2"
29.2"
25.0"
16.4"
14.6"
3.6"
3.0"
24.6"
Side View
A10
A11
19.2"
14.0"
20.0"
Front View
14.0"
24.6"
A10
A11
20.0"
Top View

Figure 3.3. Example of Firebox Volume Divided Into Specific Component Volumes

Calculation of Usable Firebox Volume

A_1

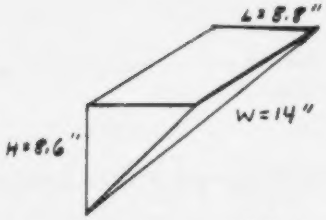


$H = 29.2 - 25.0 = 4.2$
$L = 24.6$
$W = 14$

$V = 4.2 \times 24.6 \times 14 = 1446.5\ in^3$

A_1 is not included in usable volume since it is above the baffle, and 2 inches above door opening.

A_2

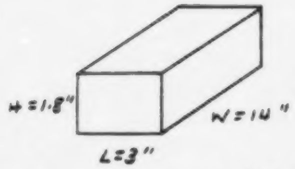


$H = 25.0 - 16.4 = 8.6$
$L = 8.8$
$W = 14$

$V = 1/2(8.8 \times 8.6) \times 14 = 529.8\ in^3$

A_2 is not included since this space is above the baffle and wood cannot reasonably be placed here.

A_3

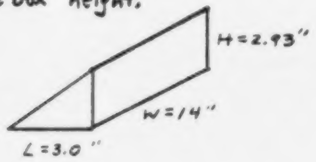


$H = 16.4 - 14.6 = 1.8$
$L = 3.0$
$W = 14$

$V = 1.8 \times 3.0 \times 14 = 75.6\ in^3$

A_3 is not included because it is directly above the firebrick, which extends more than 1/8 the usable fire box height.

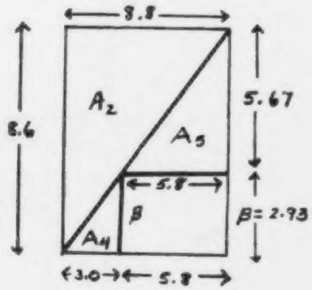
A_4



$H = 2.93$
$L = 3.0$
$W = 14$

$V = 1/2(3 \times 2.93) \times 14 = 61.53\ in^3$

(see figure to right)



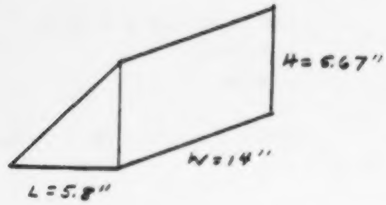
A_4 is not included for the same reason as A_3.

$$\frac{3.0}{8.8} = \frac{\beta}{8.6}$$

$\beta = 2.93$

Figure 3.4. Example Calculation of Specific Firebox Volume (Based on Components Illustrated in Figure 3.3)

A_5


H=5.67"
W=14"
L=5.8"

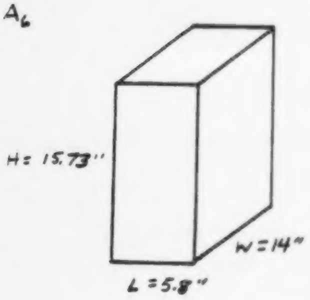
$H = 5.67$
$L = 5.8$
$W = 14$

$V = \frac{1}{2}(5.8 \times 5.67) \times 14 = 230.2 \text{ in}^3$

(see previous figure)

A_5 is included

A_6

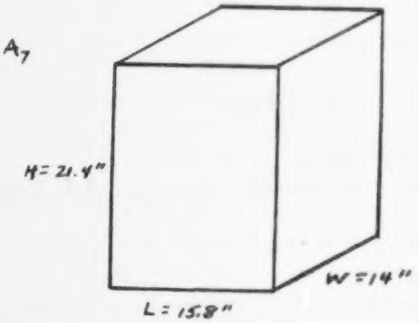

H= 15.73"
W=14"
L=5.8"

$H = (14.6 - 3.6) + 1.8 + 2.93 = 15.73$
$L = 5.8$
$W = 14$

$V = 15.73 \times 5.8 \times 14 = 1277.3 \text{ in}^3$

A_6 is included

A_7

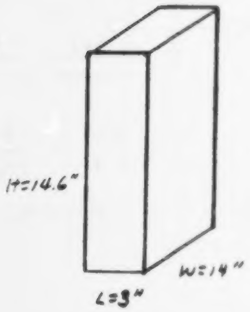

H= 21.4"
W=14"
L= 15.8"

$H = 21.4$
$L = 15.8$
$W = 14$

$V = 21.4 \times 15.8 \times 14 = 4733.7 \text{ in}^3$

A_7 is included

A_8



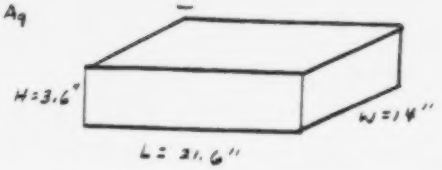
$H = 14.6$
$L = 3.0$
$W = 14$

$V = 14.6 \times 3 \times 14 = 613.2 \text{ in}^3$

A_8 is not included since firebrick is a permanent component.

Figure 3.4. Continued.

A_9

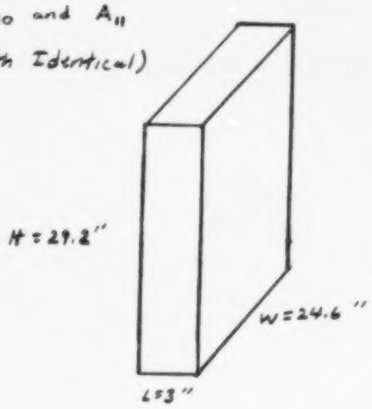


$H = 3.6$
$L = 24.6 - 3.0 = 21.6$
$W = 14$

$V = 3.6 \times 21.6 \times 14 = 1088.6\ in^3$

A_9 is not included because this space includes the permanent grate and the space under the grate.

A_{10} and A_{11}
(Both Identical)



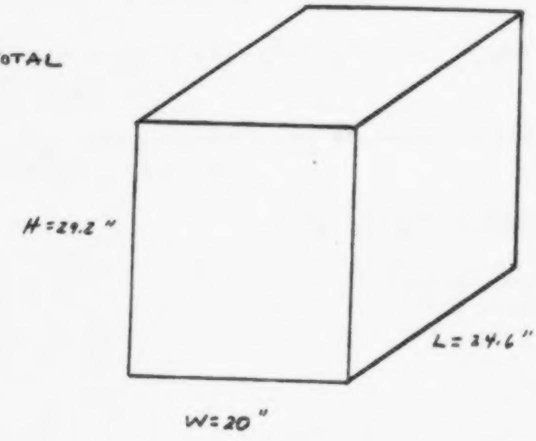
$H = 29.2$
$L = 3.0$
$W = 24.6$

$V_{10} = 29.2 \times 3 \times 24.6 = 2155.0\ in^3$

$V_{11} = 2155.0\ in^3$

A_{10} & A_{11} are not included because firebrick is a permanent component.

A_{TOTAL}



$H = 29.2$
$L = 24.6$
$W = 20$

$V_T = 29.2 \times 24.6 \times 20 = 14366.4\ in^3$

Figure 3.4. Continued.

Firebox Volume is Calculated 2 ways:

1st method

Usable firebox Volume = sum of usable components

Usable firebox Volume = $A_5 + A_6 + A_7$

$= 230.2 + 1277.3 + 4733.7$

$= 6241.2 \text{ in}^3$

$= 6241.2 \text{ in}^3 \times \dfrac{1 \text{ ft}^3}{(12)^3 \text{ in}^3}$

$= 3.61 \text{ ft}^3$

2nd method (check)

Usable firebox Volume = Total Volume − Unusable Volume

Usable firebox Volume = $A_{Total} - (A_1 + A_2 + A_3 + A_4 + A_8 + A_9 + A_{10} + A_{11})$

$= 14366.4 - (1446.5 + 529.8 + 75.6 + 61.53 + 613.2$
$+ 1088.6 + 2155 + 2155)$

$= 14366.4 - 8{,}125.2$

$= 6241.2 \text{ in}^3$

$= 3.61 \text{ ft}^3$

Figure 3.4. Continued.

3.2 Wood Heater Installation

After determination of usable firebox volume, the next recommended pretest activity is installation of the wood heater. This subsection presents guidelines for installing the wood heater flue pipe, optional liquid seal, and wood heater catalyst and surface temperature monitors. Figure 3.5 illustrates components associated with wood heater and flue pipe installation.

3.2.1 Wood Heater and Flue Pipe - The wood heater should be placed on a platform scale and fitted with a clean, steel flue pipe that extends 2.45 to 2.75 m (8 to 9 ft) above the top of the platform scale. If a heat insulation shield is used between the wood heater and the platform scale, the height should be measured from this surface. An insulated solid pack chimney section must extend 4.3 to 4.9 m (14 to 16 ft) above the platform scale. Both the steel flue pipe and ISP should be assembled leak-free and should be of a diameter specified as suitable by the wood heater manufacturer. All flue pipe sampling locations should be identified and port holes cut prior to assembling the flue pipe. Figure 3.6 shows Method 5H sampling port locations and allowable height specifications. The wood heater flue pipe should be installed so that exhaust gases are released into an airspace inside the test facility, or into a space freely communicating with the test facility. Hoods or other devices for capturing and venting exhaust gases to the outside are recommended.

Since the required length of ISP chimney sections typically weighs between 23 and 36 kg (50 and 79 lb), this chimney section should be solidly attached to the test facility ceiling or walls. Factory-made support assemblies are commercially available and may be used in suspending the ISP. Assemblies used for securing ISP sections should allow vertical movement of the flue so that the distance between the flue pipe exhaust and venting or dilution tunnel hood may be adjusted. Solid support of the ISP section requires that a liquid seal or similar device be installed in the flue pipe

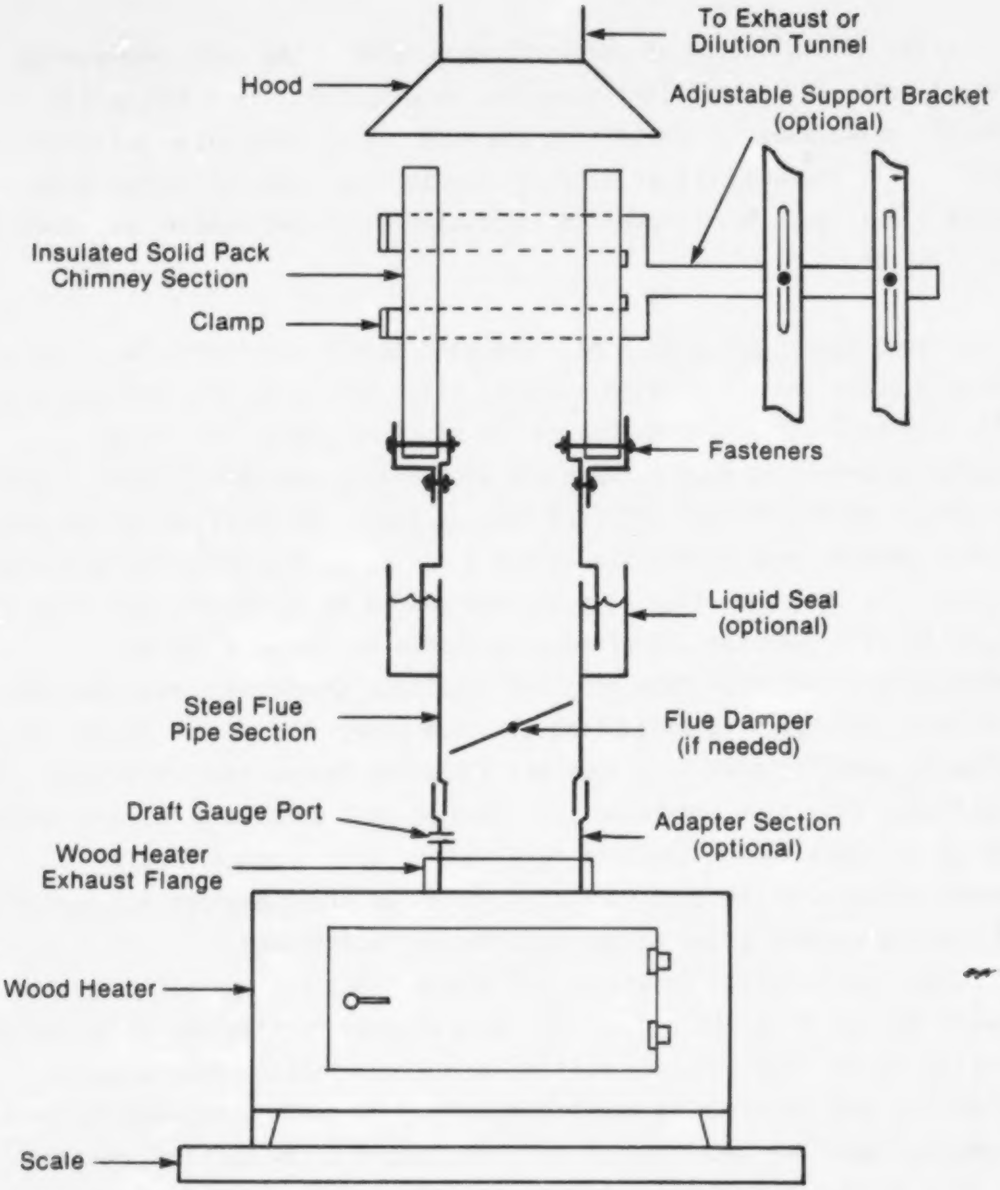

To Exhaust or Dilution Tunnel
Hood
Adjustable Support Bracket (optional)
Insulated Solid Pack Chimney Section
Clamp
Fasteners
Liquid Seal (optional)
Steel Flue Pipe Section
Flue Damper (if needed)
Draft Gauge Port
Adapter Section (optional)
Wood Heater Exhaust Flange
Wood Heater
Scale

Figure 3.5. Wood Heater and Flue Installation

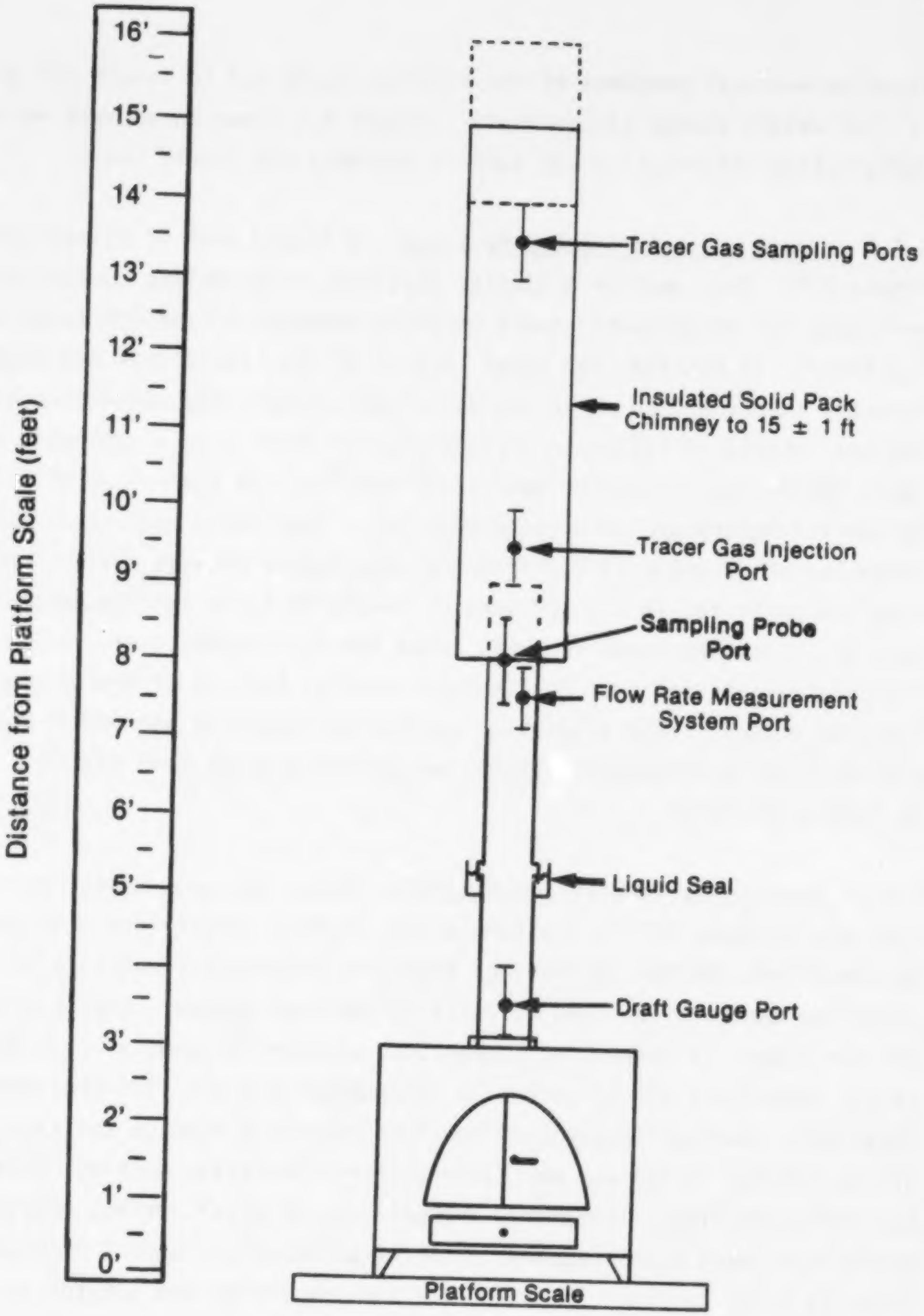

16'
15'
14'
13'
12'
11'
10'
9'
8'
7'
6'
5'
3'
2'
1'
0'
Distance from Platform Scale (feet)
Tracer Gas Sampling Ports
Insulated Solid Pack Chimney to 15 ± 1 ft
Tracer Gas Injection Port
Sampling Probe Port
Flow Rate Measurement System Port
Liquid Seal
Draft Gauge Port
Platform Scale

Figure 3.6. Wood Heater Installation with Flue Pipe Sampling Port Locations

to allow vertical movement of the platform scale and to ensure the quality of fuel weight charge measurements. Figure 3.5 shows an example wood heater installation illustrating ISP support assembly and liquid seal.

3.2.2 Liquid Seal and Adapter Sections - A liquid seal is illustrated in Figure 3.7. This seal or a similar airtight, frictionless connection is necessary for unobstructed scale platform movement if the ISP is solidly supported. If desired, the upper section of the liquid seal can mount directly onto the ISP, or it can attach to a steel pipe connection piece. The seal should be filled to a predetermined level with a synthetic oil that has a boiling point greater than 177^{0}C (350^{0}F), and the volume of oil should be checked before and after each test run. The liquid seal should be installed about 0.6 m (2 ft) from the wood heater exhaust flange. Any sampling ports not in the ISP section should be above the liquid seal section. Locating sampling ports below the liquid seal could result in inaccurate or biased test fuel weight readings because of the weight of sampling probes. Such a location could also result in accidental bumping of flue pipe walls by sampling probes and possibly cause some platform scales to lose their tares.

3.2.3 Wood Heater Temperature Monitors - After the wood heater and flue pipe are in place on the platform scale, surface temperature monitors should be installed. Method 28 requires that five temperature monitors be installed centrally on five surfaces of the wood heater: top, bottom, back, and two sides. Placement of temperature monitors on unusually shaped heaters (e.g., spherical) should generally correspond to these five proximate locations. Surface temperature monitors must be placed on the exterior wall of the firebox inside any heat shield, air circulation ducting, tile or high-mass covering. Therefore, installation of these surface temperature monitors in many cases requires drilling of holes or removal of exterior tiles in order to properly attach the sensing tip of the monitor to the exterior wall of the firebox. Figures 3.8 and 3.9 show surface temperature monitor locations and recommended methods of thermocouple attachment for several wood heater types.

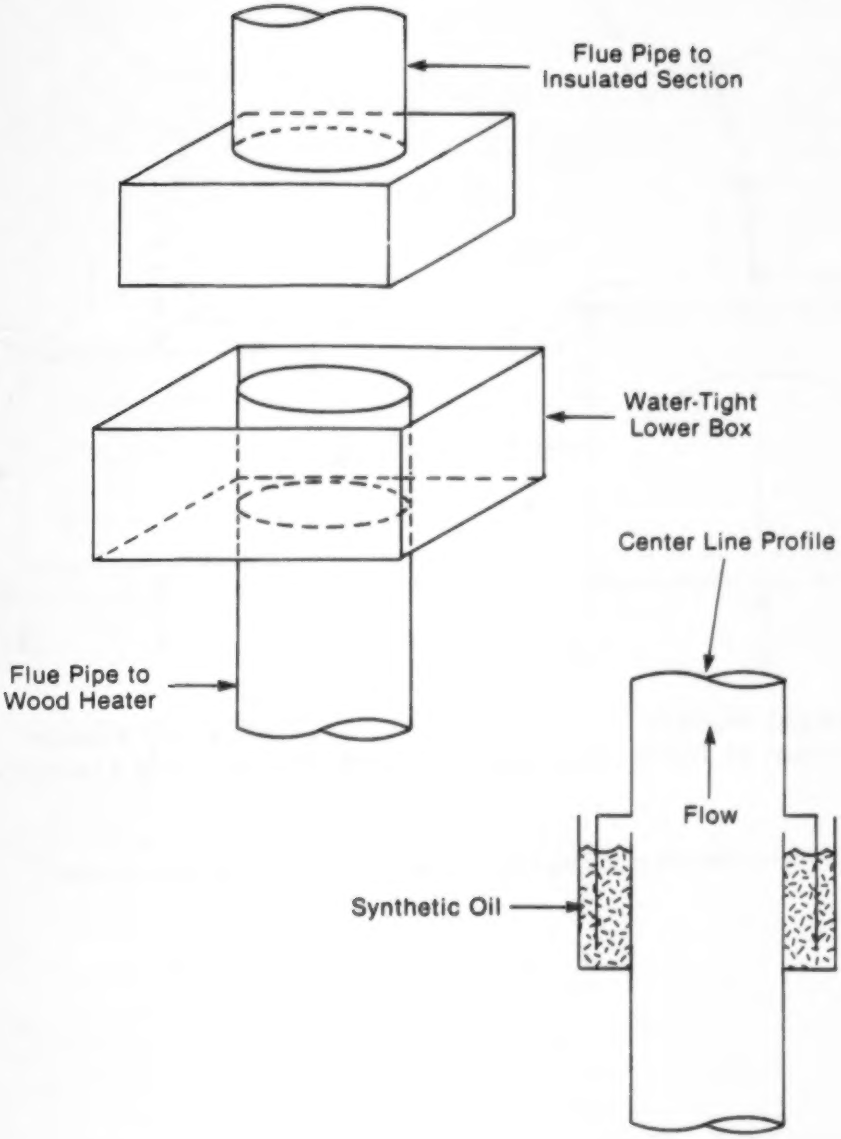
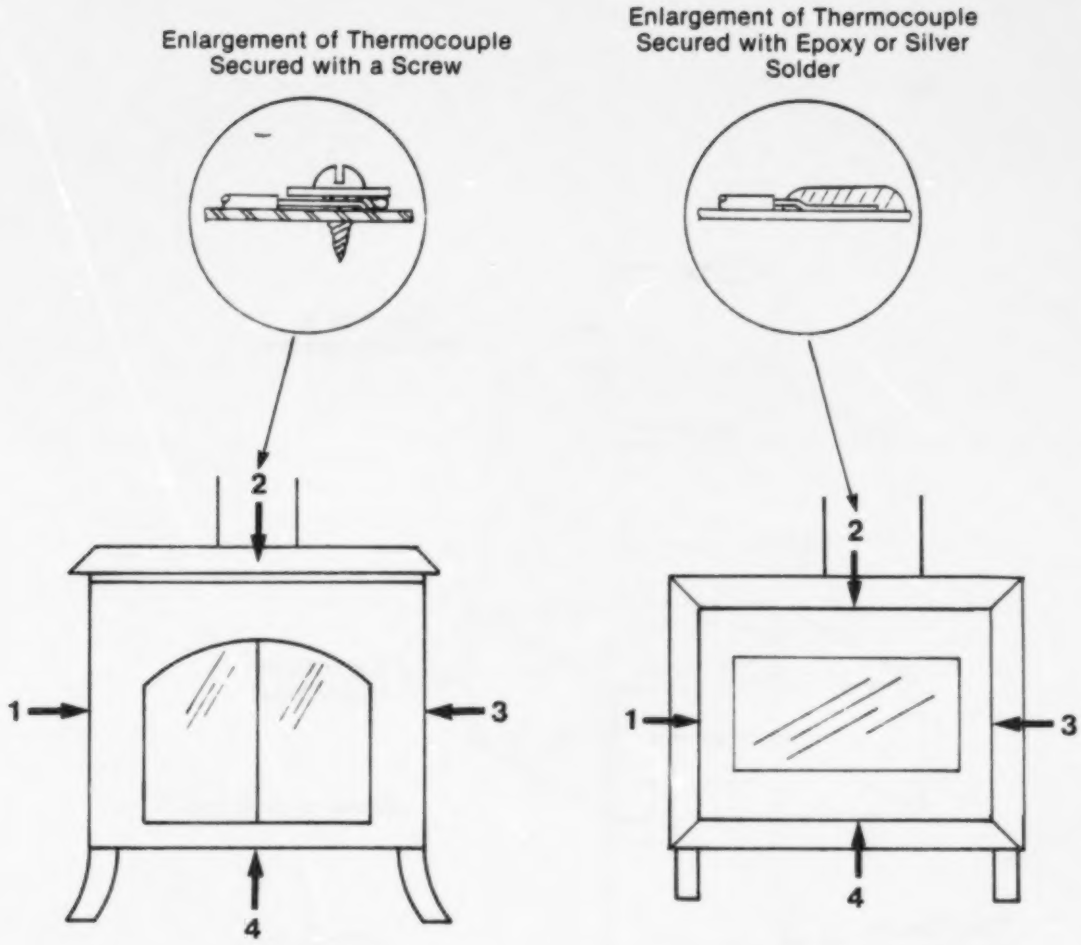

Flue Pipe to
Insulated Section
Water-Tight
Lower Box
Center Line Profile
Flue Pipe to
Wood Heater
Flow
Synthetic Oil

Figure 3.7. Liquid Seal

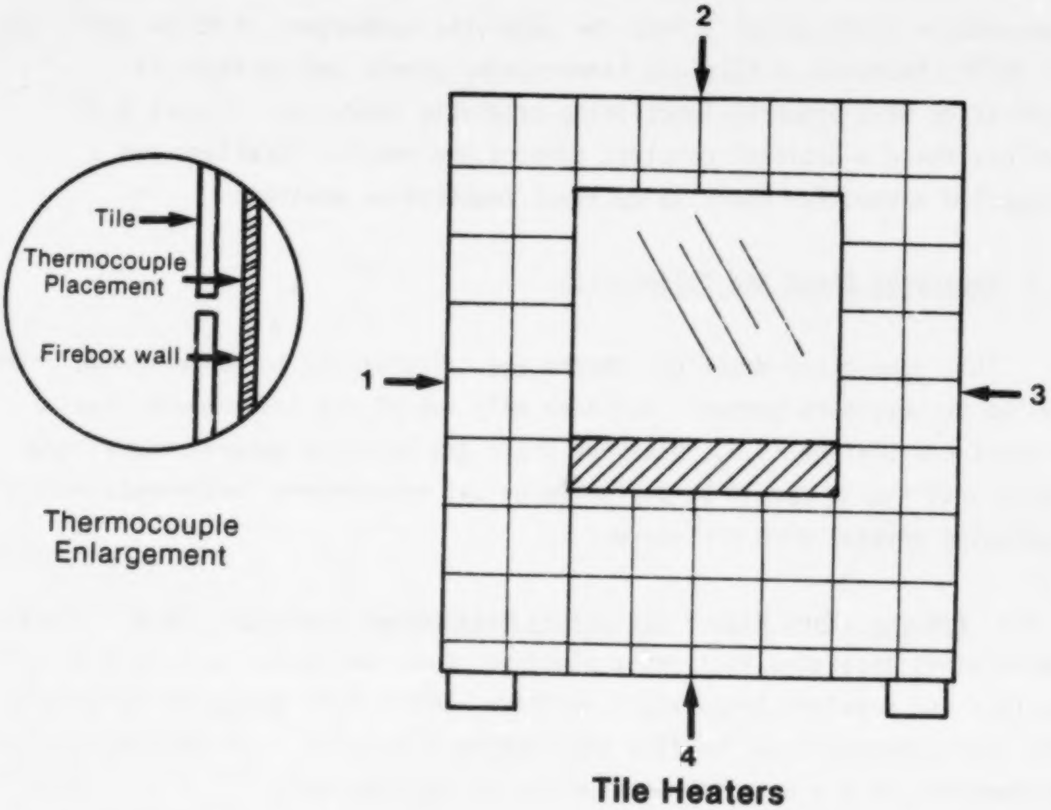

Enlargement of Thermocouple Secured with a Screw
Enlargement of Thermocouple Secured with Epoxy or Silver Solder
1
2
3
4
1
2
3
4

Radiant Heater
(External Placement of Thermocouples)

Circulating Heater
(Internal Placement of Thermocouples)

(A fifth thermocouple is located on the back surface of the wood heater.)

Figure 3.8. Placement of Thermocouple Monitors


Tile
Thermocouple Placement
Firebox wall
Thermocouple Enlargement
2
1
3
4
Tile Heaters

(An additional thermocouple, not shown on this diagram, is located on the back surface of the wood heater.)

Figure 3.9. Placement of Thermocouple on Internal Surface of Wood Heater

For catalytic wood heaters, one additional temperature monitor must be located about 25 mm (1 in.) downstream from the centroid of the catalytic combustor face area. An optional temperature monitor located about 25 mm (1 in.) upstream of the combustor is recommended to allow monitoring of the temperature differential across the catalytic combustor. A 93 to 149^{o}C (200 to 300^{o}F) increase in flue gas temperatures across the catalyst is indicative of a properly functioning catalytic combustor. Figure 3.10 depicts these additional catalyst temperature monitor locations and a suggested method for mounting catalyst temperature monitors.

3.3 Apparatus Check and Calibration

This subsection describes checks and calibrations to be performed prior to the pretest burn period. Although only two of the instruments require pretest calibration (i.e., platform scale and moisture meter), visual and functional checks should be performed on all measurement instruments before beginning pretest burn procedures.

3.3.1 Process (Wood Heater Operation) Measurement Apparatus Check - Process measurement apparatus includes a platform scale for measuring burn rate, surface and catalyst temperature monitors, and a draft gauge for recording the static pressure in the flue pipe during a test run. Calibration procedures are discussed in Section 2.0 of this manual.

The most important process measuring instrument is the platform scale. Method 28 requires that scale calibration be checked with a single-point audit before each certification test begins. To ensure quality data, this single-point calibration check should be performed before and after each test run. Platform scale calibration checks should be performed at temperatures commonly incurred during emission testing, since the accuracy of some scales is known to be affected by temperature.

The draft gauge (manometer) should be checked for proper fluid level (if liquid type) or battery condition (if battery operated). If the induced draft reading is 0.0 or below the limit of detection, the gauge may be

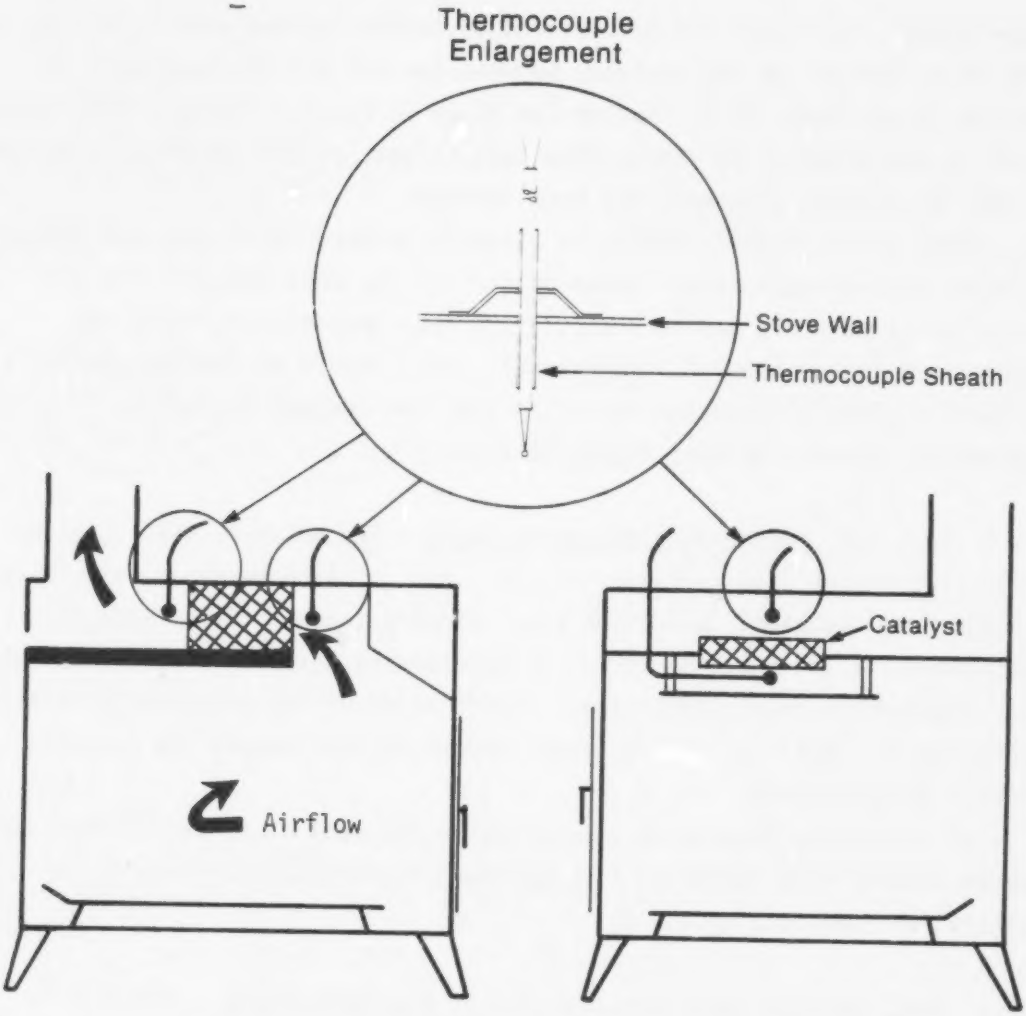

Thermocouple Enlargement
Stove Wall
Thermocouple Sheath
Catalyst
Airflow

Figure 3.10. Placement of Thermocouple Around the Catalyst

inoperative. Operation can be verified by increasing the exhaust system flow or by decreasing the distance between the ISP and the hood until a reading is obtained, or by placing the gauge in front of a fan. The induced draft is not expected to change from test to test unless the exhaust volume or the ISP-to-hood clearance has been changed.

Temperature monitors should be visually checked for insulation breaks or other defects upon installation on (or in) the wood heater. The installed temperature monitors should all read approximately the same temperature (i.e., ambient temperature). They should be checked against a mercury-in-glass thermometer to verify that the readout device is operational and to identify faulty thermocouples.

3.3.2 Test Fuel Measurement Apparatus Check - The moisture meter must be calibrated before each certification test run. The recommended calibration procedure is described in Section 2.8.2 of this manual. Since wood temperature is an important factor in determining moisture content, the test fuel temperature measurement (i.e., verification of the temperature control system in the test fuel storage area) should be made before the moisture content is determined.

If a separate balance is used to weigh the test crib, its calibration can be checked with the Class F weight used for the platform scale calibration (see Section 2.1.2).

3.3.3 Test Facility Condition Measurement Apparatus Check - The test facility temperature monitor should be checked against the wood heater temperature monitors. The temperature readings should be approximately the same prior to starting the pretest burn. The relative humidity gauge (hygrometer) should be checked for proper water level (wet bulb type). The air pressure gauge (barometer) should be checked against a local weather station reading and adjusted for altitude differences between the station and the test facility. To correct for altitude, subtract 2.5 mm Hg/30 m (0.1 in. Hg/100 ft) from the station value for an elevation increase or add the same for an elevation decrease.

3.4 Catalytic Combustor and Wood Heater Aging

Wood heaters and catalysts (if so equipped) must be aged before certification tests are performed (i.e., before the pretest burn). Aging conditions gaskets and sealing materials used in wood heater construction, burns off paint or solvents that could potentially affect emissions, and identifies catalysts that may be subject to rapid deterioration.

3.4.1 Catalyst-Equipped Wood Heater - A catalyst-equipped wood heater (with a new catalyst) must be aged for a period of at least 50 h at a medium burn rate (Categories 2 or 3 - 0.80 to 1.90 kg/h). The catalyst should be aged in the heater to be tested. For the aging burn, either dimensional Douglas fir fuel or cordwood may be used. If cordwood is used, its moisture content must measure between 15 and 25% (wet basis). Dimensional Douglas fir should measure in the specified test fuel range of 16 to 20% (wet basis).

During the aging burn, the hourly catalyst temperature measurements and total hours of operation should be recorded. An example data form for reporting data from aging procedures in shown in Figure 3.11. This documentation should be submitted with compliance test reports.

3.4.2 Noncatalyst Wood Heater - A noncatalyst wood heater must be aged or burned for 10 h at the same burn rate and fuel requirements listed above for catalyst-equipped wood heaters. The same data form (Figure 3.11) can be used for documenting both catalyst and noncatalyst wood heater aging.

3.5 Secondary Air Validation Procedure

Method 28 allows a single adjustment to be made to secondary air supplies during a certification test run. However, air supplies must meet one of the following criteria in order to be defined as secondary air for emission testing purposes:

Wood Heater and Catalyst Aging

1.0 Wood Heater Information

Wood Heater Manufacturer Ajax Inc
Wood Heater Model SLOWBURN
Catalyst Manufacturer N/A
Aging Procedures Performed By Bill Smith

2.0 Aging Documentation

Date	Clock Time	Cumulative Aging Time (h)	Test Fuel Scale Reading (lb)	Catalyst Inlet Temperature (°F)	Catalyst Outlet Temperature (°F)
7-25-87	6:00 AM	0	25.0	N/A	N/A
	7:00	1	21.3		
	8:00	2	18.3		
	9:00	3	15.5		
	10:00	4	12.9		
	11.00	5	10.6		
	12.00	6	8.5		
	1:00 PM	7	6.5		
	2:00	8	4 6		
	3:00	9	3.1		
	4:00	10	2.0		
	5:00	11	1.2		
		12			
		13			
		14			
		15			
		16			
		17			
		18			
		19			
		20			
		21			
		22			
		23			
		24			
		25			
		26			
		27			
		28			
		29			
		30			

Figure 3.11. Example Data Form for Documenting Wood Heater and Catalyst Aging

3.0 Fuel Additions

Date	Clock Time	Weight of Fuel Addition (lb)	Initials of Operator	Fuel Type: Cordwood or Dimensional
7/30/87	8:00	2.5 lb	BJS	2×4s

Figure 3.11. (continued)

1. Design drawings must show that air is introduced into a chamber outside the firebox, or

2. Test procedures must be performed to demonstrate that air supply adjustments do not result in a burn rate change of more than 25%.

If the manufacturer's instructions require adjustments to secondary air supplies during emission testing and the design drawings do not show introduction of air into a separate chamber, the following procedure must be followed prior to emission testing to determine if air adjustments will be allowed.

1. Install the wood heater as described in Method 28 - Section 6.2.1, and prepare a test fuel crib as described in Method 28 - Sections 4.2 to 4.3. Build a fire in the wood heater in accordance with the manufacturer's instructions and conduct a pretest burn as described in Method 28 - Section 6.3.

2. With air supply controls set according to manufacturer's instructions, conduct a test run in burn rate Category 1. This procedure should be conducted as described in Method 28 - Section 6.4, except that only fuel weight data must be monitored and recorded.

3. After 25% of the fuel has been consumed, adjust the secondary air supply controls to an "adjusted" setting as described in the manufacturer's instructions and record 5-min fuel weight readings for a 20-min period.

4. Adjust the secondary air supply controls to their original positions and record 5-min fuel weight readings for an additional 20 min.

5. Then reset the secondary air controls to their "adjusted" position. Steps 3, 4, and 5 are one cycle. This cycle should be conducted three times equally spaced over the entire burn period as defined in Method 28 - Section 6.4. Note: For shorter runs, cycles may overlap (i.e., Step 3 of Cycle 1 can be the same time period as Step 1 of Cycle 2).

6. Calculate the average burn rate change for each of the three cycles (see Section 6.0 of this manual). If the adjustments result in an average burn rate change of more than 25%, the air supply is considered to be a primary air supply, and no

> adjustments to this air supply are allowed during the certification test run. Otherwise, the air supply is considered to be a secondary air supply, and one adjustment is permitted during each test run.

Figure 3.12 shows an example data form and worksheet for assisting testers in documenting secondary air validation procedures.

3.6 Test Fuel Measurements

3.6.1 Moisture Content - The moisture content of the test fuel must be measured within 4 h of the test run. The moisture meter should be stored with the fuel so that it is at the same temperature. Each piece of fuel (not including spacers) must be measured on three sides (not ends). Moisture readings should be taken at locations on the test fuel pieces that have relatively straight grain and are free of defects. The moisture meter electrodes should be aligned with the grain of the wood and inserted 1/4 the thickness of the fuel piece or 19 mm (0.75 in.), whichever is greater. Especially at higher moisture content levels, the readings should be taken as soon as possible after the electrodes are driven in, since direct current meters show a drift toward lower moisture readings after voltage is applied.

For each piece, the three readings are averaged to determine the moisture content per fuel piece. The moisture content of all fuel pieces is averaged to give the test crib moisture content. Figure 3.13 shows an example form for documenting and calculating average wood moisture. Adjust the final figure for wood temperature (if required per moisture meter instructions) and convert to wet basis if the meter readings are determined on a dry basis. Wood moisture cannot be measured with confidence bu using a resistance meter when the moisture content is over 25 to 27% on a dry basis. Therefore, the averages may not accurately represent the moisture content if any single reading exceeds 25% moisture content (dry basis).

Process Phase/Secondary Air Setting (original = setting for burn rate category 1) (adjusted = per manufacturer's instructions)	Step Time		Run Time (minutes)	Fuel Weight (lb)	20-Minute Average Burn Rate BR cycle step = $\frac{60 \times (W_{cycle,3} - W_{cycle,0})}{20 \times 2.205}$ (Wet kg/hr)	
Start of Run/original			0	20.0	= W_0 (Note: $W_{1,0}$ must be ≤W_0 × 0.75)	
Cycle 1						
Step 1/adjusted	0		30	15.0	= $W_{1,0}$	
	5		35	14.2		
	10		40	13.7		BR_{11} = 3.27
	15		45	13.1		
Step 2/original	20	0	50	12.6	= $W_{1,1}$	
		5	55	12.1		
		10	60	11.6		BR_{12} = 2.31
		15	65	11.2		
Step 3/adjusted (Note: cycle 1, step 3 may overlap with cycle 2, step 1)	0	20	70	10.9	= $W_{1,2}$	
	5		75	10.5		BR_{13} = 2.59
	10		80	10.1		
	15		85	9.6		
	20		90	9.0	= $W_{1,3}$	
Cycle 2						
Step 1/adjusted	0		100	8.5	= $W_{2,0}$	
	5		105	8.0		BR_{21} = 2.18
	10		110	7.6		
	15		115	7.2		
Step 2/original	20	0	120	6.9	= $W_{2,1}$	
		5	125	6.6		BR_{22} = 1.90
		10	130	6.3		
		15	135	5.9		
Step 3/adjusted (Note: cycle 2, step 3 may overlap with cycle 3, step 1)	0	20	140	5.5	= $W_{2,2}$	
	5		145	4.9		BR_{23} = 2.18
	10		150	4.5		
	15		155	4.2		
	20		160	3.9	= $W_{2,3}$	
Cycle 3						
Step 1/adjusted	0		170	3.3	= $W_{3,0}$	
	5		175	2.8		BR_{31} = 1.63
	10		180	2.5		
	15		185	2.3		
Step 2/original	20	0	190	2.1	= $W_{3,1}$	
		5	195	1.9		BR_{32} = .68
		10	200	1.8		
		15	205	1.7		
Step 3/adjusted	0	20	210	1.6	= $W_{3,2}$	
	5		215	1.3		BR_{33} = 1.36
	10		220	1.0		
	15		225	0.8		
	20		230	0.6	= $W_{3,3}$	

(Note: All cycles must be complete. Use 2 cycles if necessary.)

$\overline{BR}_{1,3}$ = Avg(BR_{11}, BR_{13}, BR_{21}, BR_{23}, BR_{31}, BR_{33}) = 2.20

$\overline{BR}_2$ = Avg(BR_{12}, BR_{22}, BR_{32}) = 1.63

% Secondary Air Effect = $\frac{\overline{BR}_{1,3} - \overline{BR}_2}{\overline{BR}_{1,3}} \times 100$ = 25.9%

Figure 3.12. Secondary Air Validation Worksheet

1.0 Wood Heater Test Fuel Information

Wood Heater Manufacturer Ajax Inc
Wood Heater Model Longburn
Run Number #2
Date 7/30/87

2.0 Pretest Fuel Measurements

Piece	Length (inches)	Moisture Meter Readings (% Moisture Dry Basis)			Average % Moisture	Corrected Average*
1	10	22	21	21	21.33	N/A
2	10	23	22	24	23.00	
3	11	26	24	24	24.66	
4	10	23	23	22	22.66	
5	11	20	18	20	19.33	
6	10	21	22	22	21.66	
7	10	20	21	21	20.33	
8	11	18	19	20	19.00	
9	10	18	20	20	19.33	
10	10	20	19	20	19.66	
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

* Corrected for Moisture Meter Pin Type and Test Fuel Temperature

Figure 3.13. Documentation of Test Fuel Measurements

3.0 Test Fuel Measurements

2 × 4 Dimensional Lumber

Piece	Length (inches)	Moisture Meter Readings (% Moisture Dry Basis)			Average % Moisture	Corrected* Average
1	20	20	19	20	19.66	N/A
2	20	21	19	20	20.00	↓
3	20	22	21	21	21.33	
4	20	20	21	20	20.33	
5	20	20	21	21	21.66	
6						
7						
8						

4 × 4 Dimensional Lumber

Piece	Length (inches)	Moisture Meter Readings (% Moisture Dry Basis)			Average % Moisture	Corrected* Average
1	20	23	22	23	22.66	N/A
2	20	22	22	23	22.33	
3	20	24	23	23	23.33	
4						
5						
6						
7						
8						

Overall Test Fuel Moisture 21.41 % MC dry basis

* Test Fuel Temperature 70°F

Correction Facor for Pin Type, and Fuel Temperature 1.0 (calibrated at 70°F)

Clock Time of Moisture Readings 6:00 AM

4.0 Test Fuel Crib

Weight of Test Charge 25 (lbs)

Number of Spacers 32

Diagram of Test Fuel Crib

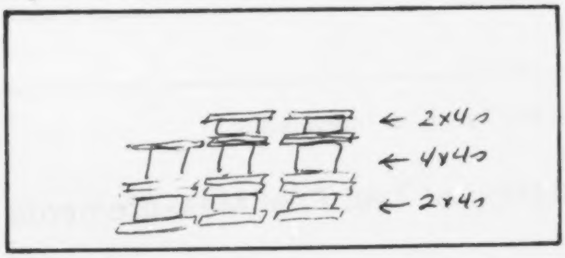


Figure 3.13. (continued)

3.6.2 Test Fuel Temperature - The test fuel temperature must be known in order to get an accurate moisture content reading. The only reliable way to get the wood temperature is to measure the temperature at which the wood has been stored for 24 h. Test fuel temperature should be reported with the moisture content measurement in the certification test report.

3.7 Test Fuel Crib Construction

Construction of the test fuel crib is important because the quantity of fuel burned and the arrangement of the test fuel pieces affect emissions sampling. In order to eliminate variations in test fuel loading practices, Method 28 provides specifications for building the test fuel crib. Building the test fuel crib consists of selecting the proper fuel dimensions, determining the test fuel charge density, and arranging the test fuel pieces. Each of these three activities is discussed in this section.

3.7.1 Fuel Dimensions - The dimensions of the test fuel pieces should conform to the nominal measurements of 2 x 4 and 4 x 4 lumber. The length of the test fuel pieces should be approximately 5/6 the length of the usable firebox. For the firebox shown in Figure 3.2, the length of the usable firebox is 21.6 in. Therefore, the length of the test fuel pieces should be approximately 18 in. (5/6 x 21.6 in.). The proper fuel dimensions (2 x 4 versus 4 x 4) should be determined in relation to the appliance firebox volume according to the guidelines listed below:

- If the usable firebox volume is less than or equal to 0.043 m^3 (1.5 ft^3), use 2 x 4 lumber.
- If the usable firebox volume is greater than 0.043 m^3 (1.5 ft^3) and less than or equal to 0.085 m^3 (3.0 ft^3), use 2 x 4 and 4 x 4 lumber. About half the weight of the test fuel charge should be 2 x 4 lumber, and the remainder should be 4 x 4 lumber.
- If the usable firebox volume is greater than 0.085 m^3 (3.0 ft^3), use 4 x 4 lumber.

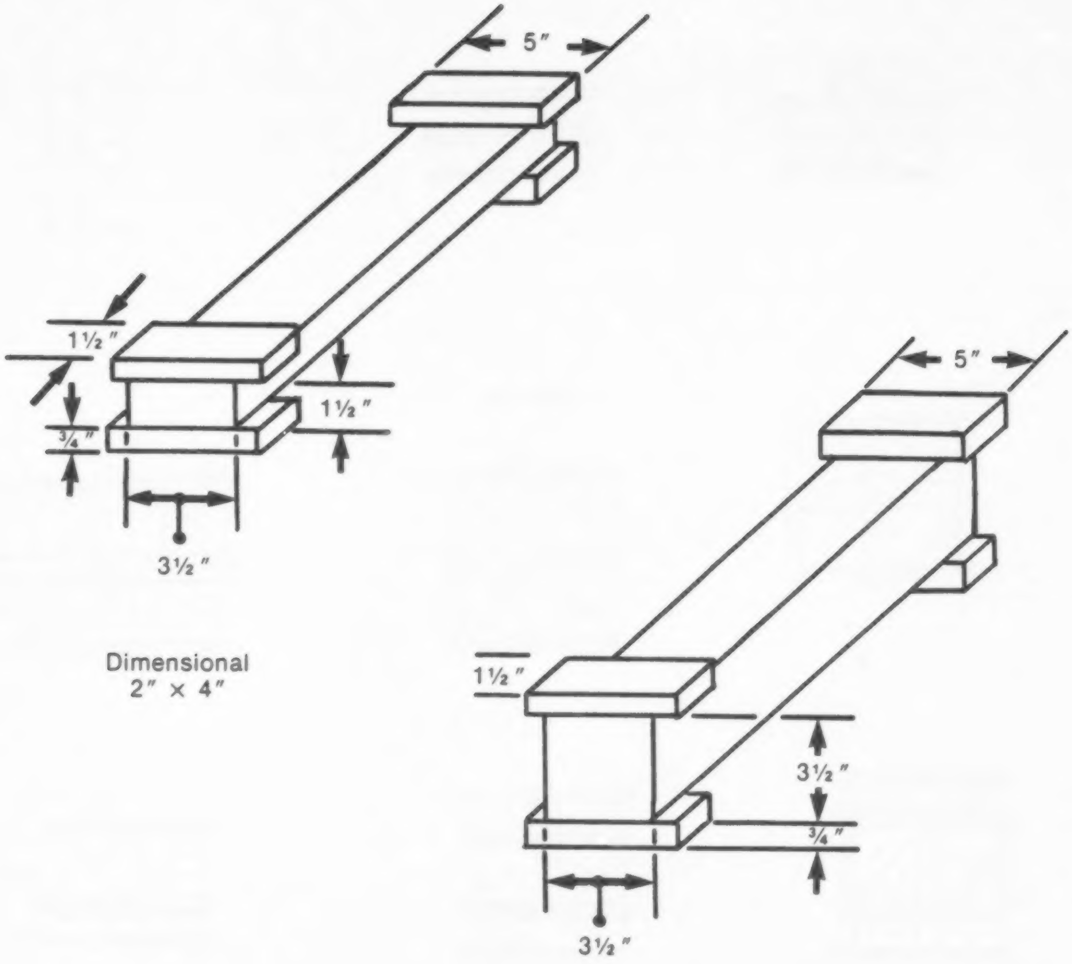
In addition to the test fuel pieces, test fuel spacers constructed of air-dried Douglas fir lumber are also required. The spacers should be 130 x 40 x 20 mm (5 x 1.5 x 0.75 in.).

3.7.2 Test Fuel Charge Density - The test fuel charge density is defined as the weight of the as-fired test fuel charge per unit volume of usable firebox. The test fuel charge density should be 7 ± 0.7 lb/ft^3 (112 ± 11.2 kg/m^3) of usable firebox volume on a wet basis. To determine the weight (lb) of test fuel required for each load, first measure the usable firebox volume (refer to Section 3.1), and then multiply the usable firebox volume (ft^3) by 7 ± 0.7 lb/ft^3. For the example shown in Figure 3.2, the usable firebox volume was calculated to be 3.61 ft^3. Therefore, the weight of the test fuel charge should be 25.3 ± 2.53 lb (3.61 ft^3 x 7 ± 0.7 lb/ft^3). The weight of the test fuel charge should include both the test fuel pieces and spacers.

3.7.3 Crib Arrangement - The crib arrangement consists of the test fuel pieces and test fuel spacers. Once the test fuel pieces have been cut to their proper dimensions, the spacers should be attached to the test fuel pieces with uncoated, ungalvanized nails or staples as illustrated in Figure 3.14. When stacking difficulties are encountered, all piece lengths should be adjusted uniformly to remain within the specified loading density. The shape of the test fuel crib should be geometrically similar to the shape of the firebox volume. Spacers on the top of the uppermost layer of the fuel crib are optional.

If the usable firebox volume is between 0.043 and 0.085 m^3 (1.5 and 3.0 ft^3), alternate the piece sizes in vertical stacking layers to the extent possible. For example, place 2 x 4s on the bottom layer in direct contact with the coal bed and 4 x 4s on the next layer, etc. (see Figure 3.15).

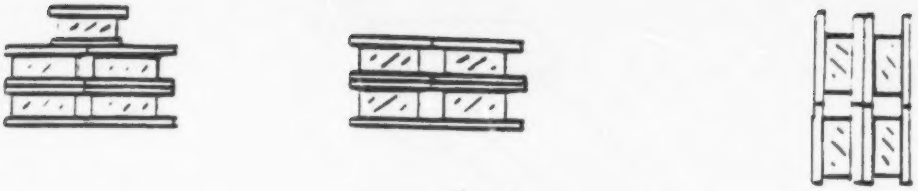
When loading test fuel in wood heaters having unusual or unconventional firebox designs, maintain air space intervals between the test fuel pieces and follow the manufacturer's instructions.


5"
1½"
1½"
¾"
3½"
5"
1½"
3½"
¾"
3½"

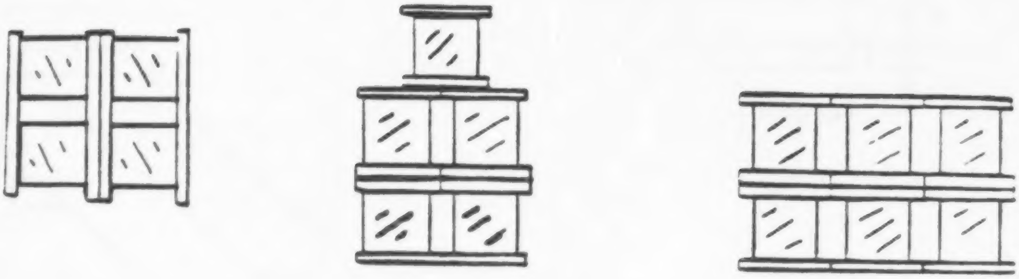
Dimensional
2" × 4"

Dimensional
4" × 4"

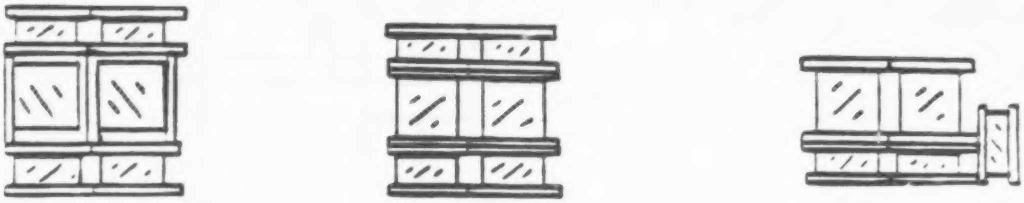
Figure 3.14. Dimensions of Test Fuel Pieces and Spacers



2 × 4



4 × 4



2 × 4 and 4 × 4

Figure 3.15. Test Fuel Crib Arrangements

3.8 Pretest Facility Condition Measurement

Prior to igniting the pretest fuel charge, various facility conditions must be measured and recorded. Report pretest facility conditions as shown on Figure 3.16.

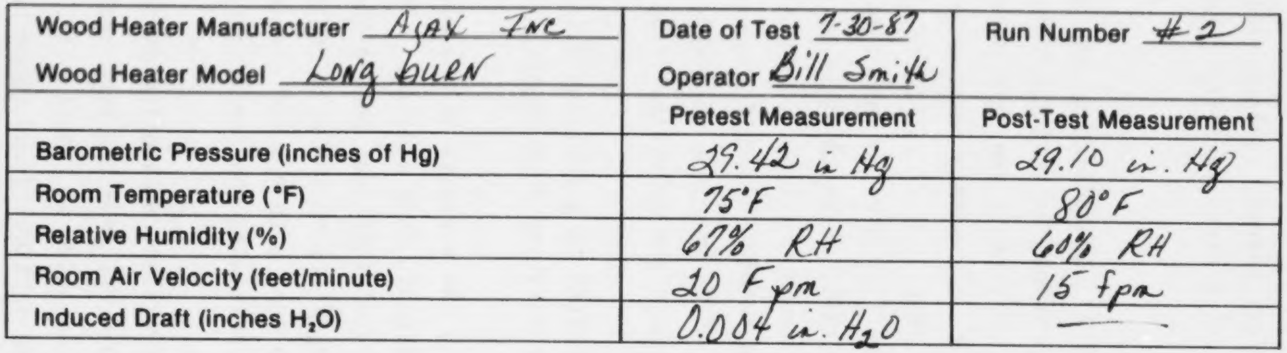
3.8.1 Induced Draft - Induced draft is the suction on the wood heater exhaust gases caused by the dilution tunnel or test facility venting system. This induced draft is measured with no fire in the wood heater, the wood heater door(s) closed, and the primary air supply controls fully open.

The induced draft must be less than 1.25 Pa (0.005 in. H_2O) when measured by a manometer fitted to the flue pipe no more than 0.3 m (1 ft) from the wood heater. The induced draft can be adjusted by changing the distance between the ISP and hood (see Figure 3.5). Increasing the distance decreases the induced draft. If the Method 5H sampling approach is used, the induced draft can also be adjusted by changing the exhaust system flow rate. Flow rates in the dilution tunnel are specifically defined by Method 5G.

Report the induced draft measurement on a test run data sheet such as Figure 3.16 and submit with the certification test report.

3.8.2 Air Velocity - Air velocity in the vicinity of the wood heater must be measured immediately before the pretest burn ignition. The anemometer should be placed horizontally at several locations around the wood heater and flue pipe. Airflow within 0.6 m (2 ft) of the wood heater and uninsulated flue pipe should be less than 0.25 m/s (50 ft/min). Record the maximum measured air velocity and submit with the certification test report.

3.8.3 Air Temperature - The air temperature monitoring device must be located approximately 1 to 2 m (3 to 6 ft) from the wood heater in the 90^{o} sector in front of the wood heater, as shown in Figure 3.17. The cylindrical shield should be oriented vertically and supported at the same



Wood Heater Manufacturer Ajax Inc Wood Heater Model Long Burn	Date of Test 7-30-87 Operator Bill Smith	Run Number #2
	Pretest Measurement	Post-Test Measurement
Barometric Pressure (inches of Hg)	29.42 in Hg	29.10 in. Hg
Room Temperature (°F)	75°F	80°F
Relative Humidity (%)	67% RH	60% RH
Room Air Velocity (feet/minute)	20 Fpm	15 fpm
Induced Draft (inches H_2O)	0.004 in. H_2O	—

Remarks

Figure 3.16. Measurement of Test Facility Conditions

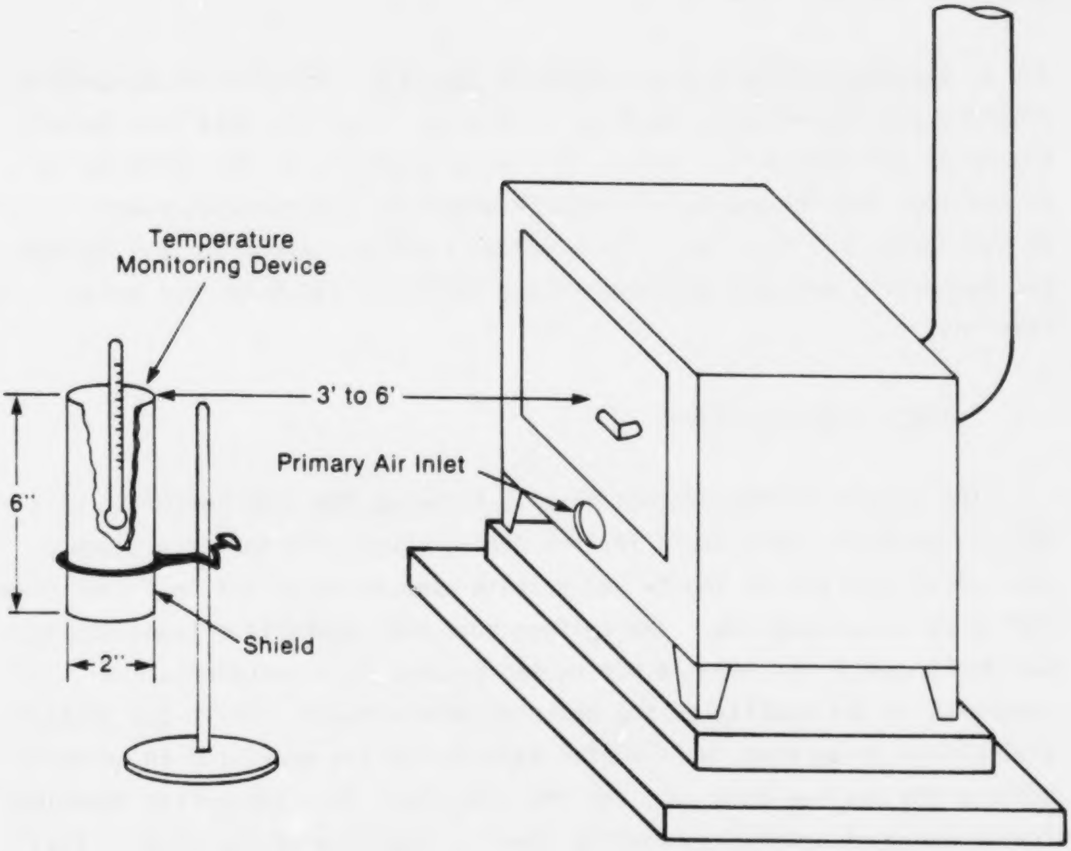

Temperature Monitoring Device
3' to 6'
6"
Primary Air Inlet
Shield
2"

Figure 3.17. Facility Temperature Monitoring Apparatus

height as the wood heater's primary air inlet. Air should be allowed to flow freely through the cylindrical shield. An air temperature between 18 and 32°C (65 and 90°F) must be maintained throughout the test run. Periodic measurements are required to document that this criterion is being met. Test facility temperature should be recorded and submitted with the certification test report.

3.8.4 Barometric Pressure and Relative Humidity - Measure the barometric pressure and the relative humidity in the test facility area just before beginning the test burn. Note: If the air pressure at the facility is controlled, the air pressure should be monitored and recorded every 10 min during the test run. For a barometrically-controlled test chamber, the barometric pressure must not exceed 1033 mbar (30.5 in. Hg) during a test run.

3.9 Pretest Burn Conditions

The purpose of the pretest burn is to bring the wood heater up to a normal operating temperature for the desired burn rate and to produce a sufficient coal bed to ignite and sustain combustion of the test fuel charge during emission sampling. The uniform coal bed, combustion temperatures, and draft conditions created during the pretest burn procedures are important to the quality of the emission measurements. While the pretest fuel charge is burning, wood heater adjustments are permitted in order to achieve the desired burn rate for the test run. This subsection describes the sequence of activities ranging from the ignition of the pretest fuel charge to the start of the test run.

3.9.1 Pretest Fuel Charge -

Fuel Requirements - The pretest fuel must meet the same fuel requirements as the test fuel, with the following exceptions. The pretest fuel dimensions should be 2 x 4s regardless of the firebox volume;

4 x 4s may be used in the same ratio as for the test fuel. The length of each pretest fuel piece must be no less than 1/3 the length of the test fuel pieces, and finally, fuel spacers are not required during the pretest fuel period.

Ignition of the Pretest Fuel - Before pretest ignition, up to 2.5 cm (1 in.) of sand or dead ash may be added according to the manufacturer's instructions. Added ash must be dried and the weight of the sand and/or ash must be included in the tare weight (i.e., it is not counted as part of the remaining pretest coal bed weight). A bed of crumpled newspaper and kindling may be used to help start the fire. Once the fire has been started, the pretest fuel pieces should be placed in the firebox chamber. A crib arrangement resembling the test fuel crib is not required.

3.9.2 Pretest Wood Heater Operation and Adjustments - During combustion of the pretest fuel, air supply controls and wood heater auxiliary equipment should be adjusted to achieve the desired burn rate. Table 3.1, presented in checklist form, summarizes the types of adjustments that are permitted during the pretest burn and when they should be performed.

Initially, the air supply controls should be set to any position that will maintain combustion of the pretest fuel. Also, the auxiliary equipment (e.g., blowers, grates) should be operated according to the manufacturer's instructions. After ignition of the pretest fuel has been established, the air supply settings should be fine-tuned to the approximate positions necessary to achieve the burn rate desired for the test run. The approximate settings must be maintained at least 1 h before the start of the test run. Although there is no limit to the number of adjustments that may be performed, none is permitted in the 15-min period before the start of the test run.

Adjustments to the pretest fuel--such as breaking up or removing large pieces of wood--may be necessary to achieve a uniform coal bed. Fuel additions or subtractions are permitted up until 15 min prior to the

TABLE 3.1. SUMMARY OF ADJUSTMENTS AND ACTIVITIES DURING PRETEST BURN PROCEDURES

Operation	Time of Operation	Action Checklist
1. If recommended, add dry ash or sand, then ignite pretest fuel	After test fuel charge has been prepared and sampling trains are prepared	______
2. Set the air inlet supply controls at any position that will maintain combustion of the pretest fuel	After ignition of the pretest fuel	______
3. Set the air inlet supply controls at the approximate positions necessary to achieve the burn rate desired for the test run	At least 1 h prior to the start of the the test run	______
4. Make any minor air inlet supply control adjustments	Up to 15 min prior to start of the test run	______
5. Add or subtract pretest fuel in order to adjust the coal bed weight and achieve uniform charcoalization	Up to 15 min prior to start of the test run	______
6. Rake the coal bed to a uniform height	Allowed any time	______
7. Start test run	When the weight of the pretest fuel is between 20 and 25% of the weight of the test fuel charge (and no adjustments, excluding coal bed rakings, were made in the last 15 min)	______
8. Record test fuel charge weight, all wood heater surface temperatures, catalyst temperatures, initial sampling measurement values; and begin particulate emission sampling	Immediately following the start of the test run	______
9. Load test fuel charge and record the platform scale reading	Within 1 min of starting the test run	______

start of the test run. Coal bed raking is allowed during the 15-min period prior to starting the test run, but the door may not remain open for more than a total of 1 min.

The coal bed should then be raked to a uniform level just prior to adding the test fuel. A uniform coal bed is evidenced by the absence of large pieces of burning wood in the coal bed and the remaining pieces being brittle enough to be broken into smaller charcoal pieces with a metal poker. Finally, the test run procedures in Section 4.0 should be reviewed and the test run can begin.

3.9.3 Pretest Data Recording - During the pretest burn period, record the pretest fuel weight, wood heater temperatures, and catalyst temperatures (see Figure 4.1).

3.10 Summary of Pretest Procedures

Figure 3.18 contains a checklist to assist in performing each of the Method 28 procedures. Table 3.2 contains an activity matrix for each of the activities discussed in this section. The purpose, acceptance limits, time, and frequency of each activity are provided.

Activity	Acceptable	
	Yes	No
Measurement of Firebox Volume		
1. Firebox dimensions measured from actual wood heater to be tested?	____	____
2. Firebox dimensions checked against engineering drawings?	____	____
3. Firebox volume calculated?	____	____
4. Volume determination documented including calculations, illustrations, and volume adjustments?	____	____
5. Volume determination independently calculated and confirmed?	____	____
Wood Heater Installation		
6. Flue pipe cleaned and assembled leak-free?	____	____
7. Flue pipe and solid pack chimney installed to allow unobstructive vertical scale movement?	____	____
8. Induced draft measured and adjusted to less than 0.005 in. H_2O?	____	____
9. Flue pipe sampling ports meet location criteria?	____	____
General Comments		

Figure 3.18. Checklist for Method 28 Pretest Procedures

Activity	Acceptable	
	Yes	No
Wood Heater Installation (Continued)		
10. Calibrated surface temperature monitors installed on top, two sides, bottom, and back of wood heater?	_____	_____
11. Calibrated temperature monitor installed approximately 1 in. downstream of catalyst?	_____	_____
Apparatus Check and Calibrations		
12. Calibration records checked and verified for surface temperature and catalyst temperature monitors?	_____	_____
13. Calibration records checked and verified for platform scale?	_____	_____
14. Calibration records checked and verified for optional fuel balance?	_____	_____
15. Platform scale single-point calibration checked and acceptable?	_____	_____
16. Moisture meter calibration performed and recorded?	_____	_____
General Comments		

Figure 3.18. Checklist for Method 28 Pretest Procedures (Continued)

Activity	Acceptable	
	Yes	No
Apparatus Check and Calibrations (Continued)		
17. Calibration records checked and verified for anemometer?	____	____
18. Calibration records checked and verified for barometer?	____	____
19. Calibration records checked and verified for relative humidity gauge?	____	____
20. Calibration records checked and verified for draft gauge?	____	____
21. Calibration records checked and verified for temperature monitors?	____	____
Catalytic Combustor and Wood Heater Aging		
22. Fuel specifications used for wood heater and catalyst aging documented?	____	____
23. Catalyst temperatures recorded during aging procedures?	____	____
24. Catalyst temperatures greater than 450°F for a minimum of 50 h?	____	____
25. Documentation demonstrating noncatalyst heater aging for a minimum of 10 h?	____	____

General Comments

Figure 3.18. Checklist for Method 28 Pretest Procedures (Continued)

Activity	Acceptable	
	Yes	No
Secondary Air Validation Procedure		
26. Operating instructions specify that secondary air supplies be adjusted during emission tests?	____	____
27. Engineering drawings show secondary air introduced into a chamber distinctly separate from primary chamber?	____	____
28. Validation procedure results demonstrate less than 25% change in burn rate?	____	____
29. All procedures and calculations documented?	____	____

General Comments

Figure 3.18. Checklist for Method 28 Pretest Procedures (Continued)

Activity	Acceptable	
	Yes	No
Test Fuel Measurements		
30. Moisture content of each test fuel piece measured?	_____	_____
31. Moisture readings, fuel temperature, and meter correction factors documented?	_____	_____
32. Test fuel pieces conform to the grade and dimensional specifications required?	_____	_____
Test Fuel Crib Construction		
33. Test fuel length approximately 5/6 the length of the firebox?	_____	_____
34. Length of each test fuel piece documented?	_____	_____
35. Test fuel crib configuration documented?	_____	_____
36. Test fuel crib meets weight and nominal size specifications?	_____	_____

General Comments

Figure 3.18. Checklist for Method 28 Pretest Procedures (Continued)

Activity	Acceptable	
	Yes	No
Pretest Facility Measurements		
37. Induced draft measured and documented?		
38. Air velocity measured and documented?		
39. Relative humidity measured and documented?		
40. Temperature measured and documented?		
41. Barometric pressure measured and documented?		
Pretest Burn Procedures		
42. Pretest fuel specifications measured and documented?		
43. Ignition procedures documented?		
44. Air supply and fuel adjustments documented?		
45. Air supply controls set a minimum of 15 min prior to start of the test run?		
46. Uniform charcoalization achieved?		
47. Pretest fuel weight criteria met?		
48. Surface temperature data recorded?		
49. Blower operated at high or according to manufacturer's instructions?		
General Comments		

Figure 3.18. Checklist for Method 28 Pretest Procedures (Continued)

TABLE 3.2. ACTIVITY MATRIX FOR PRETEST PROCEDURES

Activity	Purpose	Specifications	Time and Frequency
Measurement of usable firebox volume	Volume measurement dictates the quantity of test fuel to be used during emission tests.	Measurement must be performed as per Method 28, Section 6.2.4. Calculations and usable volume adjustments must be documented.	For each wood heater, the firebox volume is measured once by the testing team and once by the auditor. Both measurements should be performed prior to the emission test and compared.
Wood heater installation	Standardized installation specifications allow wood heaters to be tested for emissions under common conditions.	Heaters must be installed as per Method 28, Sections 6.2.1 and 6.2.2.	Installation activity should be performed prior to aging, secondary air validation, and emission testing.
Apparatus check and calibration	To check apparatus against known standards to ensure data quality.	Apparatus must meet calibration specifications described in Method 28, Section 7.	All equipment records should be reviewed prior to each emission run to ensure that calibration procedures have been performed and instruments are within allowable specifications. Wood fuel moisture meter should be calibrated before each use. A single-point calibration check should be performed on the

TABLE 3.2. ACTIVITY MATRIX FOR PRETEST PROCEDURES (Continued)

Activity	Purpose	Specifications	Time and Frequency
Apparatus check and calibration (continued)			platform scale prior to each certification run. Calibration of other equipment should be performed semiannually.
Catalytic combustor and wood heater aging	To allow seasoning of wood heater construction materials prior to emission testing. Catalytic combustor aging must be performed so that measured emission rates will be representative of 50-h catalysts.	Aging criteria as per Method 28, Section 6.1. Catalyst-equipped heaters must be aged with the combustor in place for a minimum of 50 h before testing for emissions. Noncatalyst heaters must be aged for a minimum of 10 h before testing for emissions.	Aging procedure must be performed once prior to the first emission test. Aging procedures must be performed by accredited laboratories.
Secondary air validation procedure	To determine if secondary air adjustments will be permitted during emission testing.	The validation procedure must be performed as described in Method 28, Section 6.2.7.	The procedure must be performed once (three trials) prior to the first emission test. This procedure is required only under the following conditions:

TABLE 3.2. ACTIVITY MATRIX FOR PRETEST PROCEDURES (Continued)

Activity	Purpose	Specifications	Time and Frequency
Secondary air validation procedure (continued)			(1) Secondary air adjustment is required during emission testing according to manufacturer's instructions, and (2) Design drawings do not show secondary air introduced into an area distinctly separate from the primary combustion chamber.
Test fuel measurements	To determine fuel moisture.	Test fuel must meet fuel specifications as per Method 28, Section 4.2. Fuel moisture must be between 16 and 20% moisture content on a wet basis.	Test fuel moisture content must be measured within 4 h of the start of each emission test run. The moisture content of pretest fuel and fuel pieces used for wood heater and catalyst aging must also be measured.

TABLE 3.2. ACTIVITY MATRIX FOR PRETEST PROCEDURES (Continued)

Activity	Purpose	Specifications	Time and Frequency
Test fuel crib construction	To ensure uniform stacking and spacing of test fuel pieces so that all certification emission tests will be performed with similar loading arrangements.	Test fuel charge specifications as per Method 28, Section 6.2.5.	One test fuel crib must be constructed before each certification emission test run.
Pretest facility measurements	To document that test facility conditions are within specified ranges prior to emission testing.	Ranges as specified in Method 28, Section 6.2.3.	Once before each certification emission test run.
Pretest burn	To raise the temperature of the wood heater to the expected operating range and to establish a coal bed sufficient to ignite the test fuel crib.	As per Method 28, Section 6.3.	Once immediately before each certification emission test. Pretest burn must begin a minimum of 1 h prior to starting the emission test.

4.0 TEST RUN PROCEDURES

The procedures for conducting a test run may be categorized as follows:

1. Starting the test run,
2. Test run measurements,
3. Adjustments during the test run,
4. Completion of the test run, and
5. Data recording.

The activity matrix, presented at the end of this section in Table 4.1, shows the sequence of events and the time during which each activity should be performed. Operation of the wood heater--maintaining primary and secondary air settings and operating the auxiliary equipment--is an integral part of test run procedures. The testing team should be familiar with the operation of the wood heater being tested and the activity matrix so that each activity is performed in a timely fashion and in accordance with Method 28.

4.1 Starting the Test Run

Before the test fuel is loaded and before emissions sampling begins, specific requirements for starting the test run must be satisfied. The requirements for starting a test run, as well as the activities that must be performed at the start of the test run, are presented in this section.

4.1.1 Requirements for Starting the Test Run - Two pretest fuel requirements must be satisfied before the test run is started. First, the pretest fuel must have been consumed to leave a fuel weight between 20 and 25% of the weight of the test fuel charge. For example, if a 10-kg test fuel charge is required, then the test run begins when the remaining pretest fuel weighs between 2.0 and 2.5 kg.

The second requirement is that uniform charcoalization of the pretest fuel must be achieved. That is, the pretest fuel bed should not contain large pieces of wood. This condition is achieved by breaking up the larger pieces of fuel or by removing the large pieces from the coal bed altogether. Large pieces of wood may be removed from the coal bed up to 15 min before the start of the test run. Adding fresh fuel prior to the start of the test run is not recommended unless addition of fresh fuel is necessary to satisfy the first requirement (i.e., if the remaining pretest fuel weighs less than 20% of the test fuel load). Fresh fuel will require additional time to achieve a uniform coal bed.

Wood heater or pretest fuel adjustments, other than coal raking, are not permitted within 15 min of starting the test run. If adjustments have been made within the past 15 min, then the start of the test run must be delayed until a 15-min interval without adjustment has passed. The test run starts when the conditions above have been met.

4.1.2 Final Pretest Measurements - As soon as the requirements for starting the test run have been satisfied, a member of the testing team should record the final test facility measurements (shown in Figure 3.16). The final coal bed weight, the initial weight of the test fuel charge, wood heater surface temperatures, and catalyst temperatures should be recorded as shown in Figure 4.1.

4.1.3 Emissions Sampling - Particulate emissions sampling begins after the final pretest measurements have been made and before the test fuel crib is loaded. The sampling procedures in Methods 5H or 5G should be followed.

4.1.4 Test Fuel Loading - The test fuel must be loaded within 1 min of starting particulate emissions sampling. Several factors should be considered when placing the test fuel in the firebox. The planned crib arrangements should be maintained. The test fuel spacers should be parallel to the floor of the firebox, and the spacer edges should be adjacent to each other (see Figure 3.15). To avoid any unexpected loading difficulties, the

WOODHEATER MANUFACTURER: Ajax Mfg.
WOODHEATER MODEL: Ajax Longburn
DATE OF TEST: 7-30-87
OPERATOR: Bill Smith
RUN NUMBER: 1
SHEET NUMBER: 1
FINAL COAL BED WEIGHT: 3.0

Time (min)	Test Fuel Scale Reading (lb)	Change in Test Fuel Weight (lb)	Wood Heater Surface Temperature (°F)					Catalyst Temperature (°F)		Room Temp. (°F)	Flue Draft (in. H_2O)	Remarks
			Top	Bottom	Rear	Side	Side	Inlet	Outlet			
0	14.6	—	403	381	326	442	409	398	544	71	-0.030	
5	14.0	0.6	362	366	312	386	358	416	625	71	-0.045	
10	13.8	0.2	356	370	289	342	328	356	551	72	-0.045	
15	13.5	0.3	342	366	282	319	311	362	546	72	-0.045	
20	13.3	0.2	334	349	266	304	297	365	530	72	-0.045	
25	13.1	0.2	329	337	260	298	291	406	554	72	-0.050	
30	12.7	0.4	380	330	253	304	290	551	658	72	-0.050	
35	12.1	0.6	479	330	250	320	297	652	746	71	-0.050	
40	11.7	0.4	507	330	251	334	308	643	711	72	-0.055	
45	11.3	0.4	491	330	251	345	315	528	700	71	-0.055	
50	11.0	0.3	466	329	253	350	320	497	689	71	-0.050	
55	10.6	0.4	458	327	253	354	323	523	640	72	-0.050	
60	10.3	0.3	462	325	254	357	328	458	734	72	-0.050	
65	10.0	0.3	458	323	267	366	336	469	777	72	-0.050	
70	9.6	0.4	452	321	260	383	346	517	754	73	-0.050	
75	9.2	0.4	473	319	263	407	354	594	735	72	-0.050	
80	8.8	0.4	495	317	270	427	362	612	738	72	-0.050	
85	8.5	0.3	505	315	275	446	368	580	763	72	-0.050	
90	8.2	0.3	506	314	279	462	371	600	769	73	-0.050	
95	7.9	0.3	504	313	284	471	375	612	773	73	-0.050	
100	7.6	0.3	510	314	286	473	380	620	781	73	-0.050	

Figure 4.1. Test Run Measurements Recording Sheet

crib arrangement should be tested prior to ignition to see if it will fit in the firebox. If loading difficulties result, some fuel pieces may be placed on edge. Any adjustments in the construction of the crib arrangement should be determined before the test run. For example, it may be necessary to remove spacers from the test fuel pieces in the top row so that the test fuel crib can fit into the firebox.

4.2 Test Run Measurements

Record test fuel weight, wood heater surface temperatures, catalyst temperatures, flue draft, and specific sampling train and flow rate measurements (Methods 5G or 5H) at 10-min intervals. Additional measurements that the testing team may want to record at 10-min intervals include room temperature, etc.

4.3 Adjustments During the Test Run

Once the test run has started, limited wood heater and test fuel adjustments are permitted by Method 28. The wood heater door may remain open up to 5 min after the start of the test run in order to make adjustments to the wood heater and test fuel. A discussion of the types of adjustments permitted by Method 28 follows.

4.3.1 Wood Heater Adjustments - Adjustments may be made to the secondary air supply setting and to any auxiliary equipment on the wood heater. The secondary air setting may be adjusted one time during the test run, and each piece of auxiliary equipment also may be adjusted one time during the test run. Adjustments to the primary air supply setting are not permitted. The testing team should be familiar with the manufacturer's operating instructions in order to identify any recommended adjustments before the test starts. These instructions must be submitted with the test report. Auxiliary equipment may be adjusted once during the test run, according to the manufacturer's instructions. All adjustments should be recorded as shown in the example data form in Figure 4.2.

Time of Adjustment	Description of Adjustment	Duration of Adjustment
11:00 AM	adjust fuel load	door open 15 sec.

Figure 4.2. Record of the Wood Heater and Test Fuel Adjustments

4.3.2 Test Fuel Adjustment - For test runs conducted at low burn rates, it may be necessary to adjust the test fuel load during the test run to prevent the fire from going out. A test fuel adjustment may be made only if the following two conditions apply: (1) more than 60% of the initial test fuel charge weight has been consumed and (2) more than 10 min have elapsed without a measurable (<0.05-kg, or 0.1-lb, or 1% of the test fuel weight, whichever is larger) weight change. Only one test fuel adjustment is permitted, and the time used to make this adjustment must be less than 15 sec. If the fire is in danger of going out more than one time, the wood heater is probably not designed to operate at such a low burn rate, and the test run should be conducted at another burn rate. The test fuel adjustment should also be recorded as shown in Figure 4.2.

4.4 Completion of the Test Run

The test run is completed when the weight of the test fuel charge is 0.0 kg. If the weight of the test fuel reaches 0.0 kg before the end of the 10-min data recording interval, emissions sampling may continue until the interval is completed. At the completion of the test, record all final measurements and stop particulate emissions sampling. If the testing team desires to conduct consecutive test runs, a minimum interval of 1 h must occur before another test run can be performed.

4.5 Data Recording

Pretest and test run measurements should be recorded on a form similar to that shown in Figure 4.1. Wood heater and test fuel adjustments should be recorded on a form similar to that shown in Figure 4.2. Both forms should be submitted as part of the certification test report.

TABLE 4.1. ACTIVITY MATRIX FOR TEST RUN PROCEDURES

Activity	Time of Activity
1. Start the Test Run	When the weight of the remaining pretest fuel is between 20 and 25% of the test fuel weight (and no adjustments other than coal bed raking have been made in the last 15 min).
2. Record Final Pretest Measurements a. Pretest fuel weight b. Wood heater surface temperatures c. Catalyst temperature d. Test fuel weight	Immediately following the start of the test run.
3. Begin Emissions Sampling	Immediately following the start of the test run.
4. Load Test Fuel	Within 1 min of starting the test run.
5. Record All Activity	Within 5 min of starting the test run.
6. Record Test Run Measurements a. Test fuel weight b. Wood heater surface temperatures c. Catalyst temperature d. Sampling train and flow rate measurements	At 10-min intervals following the start of the test run.
7. Make Wood Heater Adjustments (if necessary)	Once during the test run.
8. Make Test Fuel Adjustments (if necessary)	When 60% of the initial test fuel weight has been consumed and more than 10 min have elapsed without a measurable weight change.
9. Complete Test Run	When the test fuel weight is 0.0 kg.

5.0 POST-TEST PROCEDURES

5.1 Post-Test Platform Scale Audit (Optional)

The platform scale calibration should be checked after completion of the certification test to ascertain that the platform scale has maintained its calibration throughout the certification test. (Platform scales can exhibit a loss of tare memory or a tare drift during a certification test.) If the scale calibration has been checked with a Class F weight before each separate test run, any discrepancies in the final check would apply only to the last test run.

5.2 Test Facility Condition Measurements

Immediately following each test run, the air velocity, relative humidity, barometric pressure, and air temperature in the test facility must be measured as described in Section 3.8. (It is not necessary to measure induced draft at this time.) These measurements should be recorded on a form such as that shown in Figure 3.16. The test facility condition measurements must be reported with each certification test report.

5.3 Post-Test Acceptance Checks

Immediately following the completion of each test run, the wood heater surface temperature readings must be recorded. If the average surface area temperature is not within 70^{0}C (125^{0}F) of the average surface temperature at the start of the test run, the test run is not valid. The surface temperatures should be recorded on a form such as that shown in Figure 4.1 and must be reported with each certification test report.

The liquid seal oil level should also be checked following each test run. If the level has dropped to a point that corresponds to an oil weight loss of more than 0.05 kg (0.1 lb), then the data quality will be adversely affected, and details of this post-test check should be included in the certification test report. The liquid seal should be repaired before the start of the next test run if a leak is indicated.

The sampling train and other sampling equipment should also be checked for leaks following each test run according to the procedures outlined in the appropriate sampling method. Results of equipment leak checks should be included in the certification test report. If leak rates are not within the allowable specifications, the emission test run must be repeated.

6.0 CALCULATIONS

The procedures for calculating the dry burn rate and weighted average emission rate, as well as for performing calculations associated with secondary air validation, are presented in this section. Calculation sheets and example calculations are also provided, where applicable. When performing calculations, at least one extra decimal figure beyond that of the measured data should be retained. After the final calculations have been made, then the extra figures may be rounded off.

6.1 Dry Burn Rate

Calculation of the dry burn rate is required once for each test run. The dry burn rate is a function of (1) the total mass of test fuel burned, (2) the average moisture content of the test fuel charge, and (3) the test run duration. The equation for calculating the dry burn rate is:

$$BR = \left(\frac{60\ W_{wd}}{\theta}\right)\left(\frac{100 - \%M_w}{100}\right) \qquad \text{Equation 6.1}$$

Where:

BR = Dry wood burn rate, kg/h (lb/h);

W_{wd} = Total mass of wood burned during the test run, kg (lb);

θ = Total time of test run, min;

$\%M_w$ = Average moisture in test fuel charge, wet basis, %.

The total mass of wood burned during the test run and the test run duration can be taken directly from the Test Run Measurements Recording Sheet (Figure 4.1). The average moisture content can be taken from the Test Fuel Measurements Sheet (Figure 3.13). When performing the dry burn rate calculation, at least one decimal figure should be maintained depending upon the resolution of the measurement equipment (e.g., fuel moisture meter, wood heater balance).

6.2 Weighted Average Emission Rate

The weighted average emission rate is a single emission rate value for determining compliance with the standard. It is derived from the emission rates measured for each of the certification test runs. The emission rates from each test run are weighted according to the probability of the burn rate. If more than one test run is conducted at a specified burn rate category, the results from at least two-thirds of the test runs in that burn rate category should be used when calculating the weighted average emission rate. For example, if three test runs are performed with burn rates of 0.80, 1.00, and 1.24 kg/h, respectively (Category 2 burn rates), then emissions rates from at least two of the three test runs should be included in the calculation. However, emission rates from test runs that are not used to calculate the weighted average emission rate must also be reported.

The equation for calculating the weighted average emission rate is

Equation 6.2

$$E_w = \frac{\sum_{i=1}^{n} (K_i E_i)}{\sum_{i=1}^{n} K_i}$$

Where:

E_w = Weighted average emission rate, g/h;

E_i = Emission rate for test run, i, from Method 5G (adjusted) or 5H, g/h;

K_i = Test run weighting factor = $P_{i+1} - P_{i-1}$;

n = Total number of test runs;

[illegible]$_i$ = Probability for burn rate during test run, i, obtained from Table 6.1.

A worksheet for calculating the weighted average emission rate is provided in Figure 6.1. The following step-by-step procedures demonstrate the use of Figure 6.1:

TABLE 6.1. BURN RATE WEIGHTED PROBABILITIES FOR CALCULATING WEIGHTED AVERAGE EMISSION RATES

Burn Rate (kg/h-dry)	Cumulative Probability (P)	Burn Rate (kg/h-dry)	Cumulative Probability (P)	Burn Rate (kg/h-dry)	Cumulative Probability (P)
0.00	0.000	2.00	0.912	4.00	0.994
0.05	0.002	2.05	0.920	4.05	0.995
0.10	0.007	2.10	0.925	4.10	0.995
0.15	0.012	2.15	0.932	4.15	0.995
0.20	0.016	2.20	0.936	4.20	0.995
0.25	0.021	2.25	0.940	4.25	0.995
0.30	0.028	2.30	0.945	4.30	0.996
0.35	0.033	2.35	0.951	4.35	0.996
0.40	0.041	2.40	0.956	4.40	0.996
0.45	0.054	2.45	0.959	4.45	0.996
0.50	0.065	2.50	0.964	4.50	0.996
0.55	0.086	2.55	0.968	4.55	0.996
0.60	0.100	2.60	0.972	4.60	0.996
0.65	0.121	2.65	0.975	4.65	0.996
0.70	0.150	2.70	0.977	4.70	0.996
0.75	0.185	2.75	0.979	4.75	0.997
0.80	0.220	2.80	0.980	4.80	0.997
0.85	0.254	2.85	0.981	4.85	0.997
0.90	0.300	2.90	0.982	4.90	0.997
0.95	0.328	2.95	0.984	4.95	0.997
1.00	0.380	3.00	0.984	≥5.00	1.000
1.05	0.407	3.05	0.985		
1.10	0.460	3.10	0.986		
1.15	0.490	3.15	0.987		
1.20	0.550	3.20	0.987		
1.25	0.572	3.25	0.988		
1.30	0.620	3.30	0.988		
1.35	0.654	3.35	0.989		
1.40	0.695	3.40	0.989		
1.45	0.722	3.45	0.989		
1.50	0.750	3.50	0.990		
1.55	0.779	3.55	0.991		
1.60	0.800	3.60	0.991		
1.65	0.825	3.65	0.992		
1.70	0.840	3.70	0.992		
1.75	0.857	3.75	0.992		
1.80	0.875	3.80	0.993		
1.85	0.882	3.85	0.994		
1.90	0.895	3.90	0.994		
1.95	0.906	3.95	0.994		

Test Run/Number[1] (i)	Burn Rate Category	Burn Rate (BR) (dry kg/h)	Emissions (E_i) (g/h)	Probability (P_i)	Emission Weighting Factor (K_i)	Weighted Emissions
i = 1, 2, 3, ton.	Cat. 1 <0.80 Cat. 2 0.80 to 1.25 Cat. 3 1.25 to 1.90 Cat. 4 Maximum	Determined from Equation 28-2 (Listed in Ascending Order)	Determined using Equation 5G-5 or 5H-9	Interpolated Probability from Table 28-1 for each Burn Rate	$K_i = P_{i+1} - P_{i-1}$ (e.g., $K_1 = P_2 - P_0$)	$E_i \times K_i$
				$P_0 = 0$		
1	1	0.65	5.0	$P_1 =$ 0.121	$K_1 = P_2 - P_0 =$ 0.300	1.50
2	2	0.90	4.7	$P_2 =$ 0.300	$K_2 = P_3 - P_1 =$ 0.259	1.22
3	2	1.00	5.3	$P_3 =$ 0.380	$K_3 = P_4 - P_2 =$ 0.422	2.24
4	3	1.45	3.8	$P_4 =$ 0.722	$K_4 = P_5 - P_3 =$ 0.532	2.02
5	4	2.00	5.1	$P_5 =$ 0.912	$K_5 = P_6 - P_4 =$ 0.278	1.42
				$P_{n+1} = 1$		
					$\sum_{i=1}^{n}(K_i) =$ 1.791	$\Sigma(K_iE_i) =$ 8.40
				Weighted Average Emissions: (g/h)	$\frac{\Sigma(K_iE_i)}{\Sigma(K_i)} =$ 4.69	

[1] The test run with the lowest burn rate is assigned test run number 1
The test run with the next lowest burn rate is assigned number 2, etc.

Figure 6.1. Worksheet for Determining the Weighted Average Emission Rate

1. Calculate the burn rates (dry kg/h) for each certification test run by using Equation 6.1.
2. List the burn rates, in ascending order, under the Burn Rate column heading (column 3) for each test run.
3. Adjust Method 5G emissions rates to Method 5H equivalent rates by using Equation 5G-5. If dual sampling trains are used, average the rates to obtain a single value corresponding to each burn rate.
4. List the emission rates with the corresponding burn rates under the Emissions column heading (column 4).
5. Assign burn rate categories to each of the burn rates and record under the Burn Rate Category column heading (column 2).
6. Assign test run numbers to each of the certification test runs starting with run number 1 and record under the Test Run Number column heading (column 1).
7. Look up the probability for each of the burn rates listed in column 3 using Table 6.1 and record under the Probability column heading (column 5). For the example shown in Figure 6.1, the probability of the first burn rate, 0.65 kg/h, is shown in Table 6.1 to be 0.121. Therefore, $P_1 = 0.121$. Note that P_0 always equals 0, and P_{n+1} always equals 1 (where n is the number of test runs). If the exact burn rate is not shown in Table 6.1, then the probability must be estimated by using linear interpolation. Table 6.2 shows how to estimate the probability by linear interpolation.
8. Calculate the emission weighting factors (K_i) and record under the Emission Weighting Factor column heading (column 6). For example, $K_1 = (P_{1+1} - P_{1-1}) = (P_2 - P_0) = (0.300 - 0) = 0.300$.
9. Sum the emission weighting factors and record at the bottom of column 6. For this example, $\Sigma(K_i) = K_1 + K_2 + K_3 + K_4 + K_5 = (0.300 + 0.259 + 0.422 + 0.532 + 0.278) = 1.791$.

TABLE 6.2. EXAMPLE INTERPOLATION METHOD FOR DETERMINING PROBABILITIES OF BURN RATES NOT PROVIDED IN TABLE 6.1

Given: Burn rate during test run = 1.13 dry kg/h.

Find: Cumulative probability, P_i, for the burn rate 1.13 dry kg/h.

Method: Linear interpolation using the measured burn rate (1.13 dry kg/h) and the surrounding data points provided in Table 6.1.

Data Points in Table 6.1:

Burn Rate (kg/h-dry)	Cumulative Probability (P)
1.10	0.460
Measured burn rate = 1.13	Unknown probability, P_i
1.15	0.490

Assume the measured burn rate (1.13 dry kg/h) forms a straight line between the two surrounding burn rates (1.10 and 1.15 dry kg/h) given in Table 6.1.

Then the slope of the line is represented as:

$$\left(\frac{1.13 - 1.10}{1.15 - 1.10}\right) = \left(\frac{P_i - 0.460}{0.490 - 0.460}\right)$$

Solve for P_i:

$$\left(\frac{P_i - 0.460}{0.030}\right) = \left(\frac{0.03}{0.05}\right) = 0.60$$

$$P_i - 0.460 = 0.60\ (0.030)$$

$$P_i - 0.460 = 0.018$$

$$P_i = 0.478$$

Result: The cumulative probability, P_i, for burn rate = 1.13 dry kg/hr is 0.478.

10. Multiply the emission rate (E_i) (column 4) by the emission weighting factor K_i (column 6) for each test run and record in the last column. For test run i = 1, $E_i \times K_i = (E_1 \times K_1) =$ $(5.0 \times 0.300) = 1.50$.
11. Sum the weighted emissions for each test run and record at the bottom of the last column. For this example, $\Sigma(K_i \times E_i) =$ $(1.5 + 1.22 + 2.24 + 2.02 + 1.42) = 8.4$.
12. Divide the sum of the weighted emissions ($\Sigma K_i \times E_i$) by the sum of the emission weighting factors (ΣK_i) and record at the bottom of Figure 6.1. For this example, $\Sigma(K_iE_i)/\Sigma(K_i) = 8.4/1.791 = 4.69$. The weighted average emission rate for this wood heater is 4.69 g/h.

If more than five test runs are conducted, Figure 6.1, the worksheet for calculating weighted average emission rates, should be modified to include additional rows.

6.3 Secondary Air Validation

To determine if secondary air adjustments are allowed during testing, it is necessary to calculate how much the burn rate changes when the air setting is adjusted. A secondary air documentation run is begun at the air control settings for burn rate Category I. As described in Section 3.5 of this document, a secondary air validation run consists of three cycles. For each cycle, the wood heater is operated for a series of three 20-min intervals, first with the secondary air supply at an adjusted setting, next with the secondary air supply at the original setting, and finally with the secondary air supply at the adjusted position. The burn rates for each of these 20-min intervals must be calculated to determine the burn rate change for each cycle. The average of the three cycles determines the net effect of the air setting change on the burn rate. Figure 6.2 contains a worksheet to assist in calculating the percent change in burn rate when secondary air adjustments are made. The following step-by-step procedures demonstrate the use of Figure 6.2.

Process Phase/Secondary Air Setting (original = setting for burn rate category 1) (adjusted = per manufacturer's instructions)	Step Time		Run Time (minutes)	Fuel Weight (lb)		20-Minute Average Burn Rate BR cycle step = $\frac{60 \times (W_{cycle,3} - W_{cycle,0})}{20 \times 2.205}$ (Wet kg/hr)
Start of Run/original			0	20.0	= W_0 (Note: $W_{1,0}$ must be <$W_0 \times 0.75$)	
Cycle 1	0		30	15.0	= $W_{1,0}$	
	5		35	14.2		BR_{11} = 3.27
Step 1/adjusted	10		40	13.7		
	15		45	13.1		
	20	0	50	12.6	= $W_{1,1}$	
		5	55	12.1		BR_{12} = 2.31
Step 2/original		10	60	11.6		
		15	65	11.2		
	0	20	70	10.9	= $W_{1,2}$	
	5		75	10.5		BR_{13} = 2.59
Step 3/adjusted	10		80	10.1		
(Note: cycle 1, step 3 may overlap with cycle 2, step 1)	15		85	9.6		
	20		90	9.0	= $W_{1,3}$	
Cycle 2	0		100	8.5	= $W_{2,0}$	
	5		105	8.0		BR_{21} = 2.18
Step 1/adjusted	10		110	7.6		
	15		115	7.2		
	20	0	120	6.9	= $W_{2,1}$	
		5	125	6.6		BR_{22} = 1.90
Step 2/original		10	130	6.3		
		15	135	5.9		
	0	20	140	5.5	= $W_{2,2}$	
	5		145	4.9		BR_{23} = 2.18
Step 3/adjusted	10		150	4.5		
(Note: cycle 2, step 3 may overlap with cycle 3, step 1)	15		155	4.2		
	20		160	3.9	= $W_{2,3}$	
Cycle 3	0		170	3.3	= $W_{3,0}$	
	5		175	2.8		BR_{31} = 1.63
Step 1/adjusted	10		180	2.5		
	15		185	2.3		
	20	0	190	2.1	= $W_{3,1}$	
		5	195	1.9		BR_{32} = .68
Step 2/original		10	200	1.8		
		15	205	1.7		
	0	20	210	1.6	= $W_{3,2}$	
	5		215	1.3		BR_{33} = 1.36
Step 3/adjusted	10		220	1.0		
	15		225	0.8		
	20		230	0.6	= $W_{3,3}$	

(Note: All cycles must be complete. Use 2 cycles if necessary.)

$\overline{BR}_{1,3}$ = Avg(BR_{11}, BR_{13}, BR_{21}, BR_{23}, BR_{31}, BR_{33}) = 2.20

$\overline{BR}_2$ = Avg(BR_{12}, BR_{22}, BR_{32}) = 1.63

% Secondary Air Effect = $\frac{\overline{BR}_{1,3} - \overline{BR}_2}{\overline{BR}_{1,3}} \times 100$ = 25.9%

Figure 6.2. Secondary Air Validation Worksheet

1. Cycle 1, Step 1 - After at least 25% of the test fuel is consumed, adjust the secondary air supply controls to an adjusted setting, record 5-min fuel weight readings for 20 min to establish a burn rate.

   Calculate the average burn rate (wet kg/h) for the first 20-min interval using Equation 6.3. This is termed BR_{11} or the burn rate of Cycle 1, Step 1.

$$BR_{11} = \frac{(60)(\Delta W_{wd})}{20} \qquad \text{Equation 6.3}$$

Where:

BR_{11} = Wet wood burn rate, kg/h (lb/h);

ΔW_{wd} = Weight of test fuel burned during the 20-min period kg (lb) (initial test fuel weight minus the final test fuel weight).

2. Cycle 1, Step 2 - Adjust the air supply controls to the original setting (as specified in the manufacturer's instructions) and record 5-min fuel weight readings for an additional 20 min.

   Calculate the average burn rate (wet kg/h) for this 20-min interval using Equation 6.3. This value is termed BR_{12} or the burn rate of Cycle 1, Step 2.

3. Cycle 1, Step 3 - Adjust the air supply controls to the adjusted setting (as in Step 1) and record 5-min fuel weight readings for an additional 20 min.

   Calculate the average fume rate (wet kg/h) for this 20-min interval by using Equation 6.3. This value is termed BR_{13} or the burn rate of Cycle 1, Step 3. Steps 1, 2, and 3 comprise Cycle 1.

4. Cycle 2 - Repeat Steps 1, 2, and 3. Calculate BR_{21}, BR_{22}, and BR_{23}. If necessary, Cycle 1, Step 3 can coincide with Cycle 2, Step 1. This may be necessary for runs of insufficient duration for three full cycles.

5. Cycle 3 - Repeat Steps 1, 2, and 3. Calculate BR_{31}, BR_{32}, and BR_{33}. Note: If the remaining fuel weight reaches 0.0 kg before the end of Cycle 3, Step 3, Cycle 3 is not complete and is not counted in the calculations.

6. Calculate the average percent change in burn rate, % BR, as follows:

$$\%\Delta BR = \left(\frac{\overline{BR}_{1,3} - \overline{BR}_{2}}{\overline{BR}_{13}} \right)$$

Where:

$\overline{BR}_{1,3}$ = AVG (BR_{11}, BR_{13}, BR_{21}, BR_{23}, BR_{31}, BR_{33}) (the average of the adjusted settings); and

$\overline{BR}_{2}$ = AVG (BR_{12}, BR_{22}, BR_{32}) (the average of the original settings).

Figure 6.2 is an example of how to make the secondary air supply determination. If the average of the percent changes in burn rates (% BR) is less than or equal to 25%, then the air supply is considered to be a secondary air setting and one adjustment is permitted during the test run. In the example case shown in Figure 6.2, the average percent change in burn rates is greater than 25% so an air adjustment is not permitted during the test run.

7.0 MAINTENANCE

The normal use of testing equipment subjects it to extremes in temperature or other conditions that may affect the reliability of the equipment. Keeping the equipment in good operating order over an extended period of time requires knowledge of the equipment and a routine maintenance program which should be performed at least semiannually. Maintenance procedures for the various equipment are summarized in Table 7.1 at the end of this section.

7.1 Platform Scale

The platform scale should be maintained according to the manufacturer's instructions. Generally, the scale should be protected from adverse weather conditions and from sharp impacts. Once a year, the platform scale should be disassembled and cleaned.

7.2 Test Fuel Scale or Balance

The test fuel scale should be maintained according to the manufacturer's instructions. The wood storage area may not be a suitable place to store the test fuel balance due to the high humidity requirements there.

7.3 Temperature Monitors

Other than calibration and protection from physical damage, there are no maintenance requirements for the temperature monitors.

7.4 Moisture Meter

No maintenance is required for the moisture meter unless recommended by the manufacturer. The meter can be stored in the wood storage area so that its temperature equilibrates with the test fuel temperature.

7.5 Anemometer

The moving parts of a vane or propeller anemometer should be lubricated with light machine oil when calibrated or as needed.

7.6 Manometer

Check to ensure there is no discoloration or visible matter in the fluid. Once a year, the instrument should be disassembled, cleaned, and filled with fresh fluid.

7.7 Barometer and Humidity Gauge

No maintenance is required on these instruments unless recommended by the manufacturer.

TABLE 7.1. ACTIVITY MATRIX: EQUIPMENT MAINTENANCE CHECKS

Apparatus	Acceptance Limits	Frequency and Method of Measurement	Action if Requirements Are Not Met
Platform scale	No erratic behavior	Dissemble and clean yearly	Replace parts as needed
Test fuel scale or balance	No erratic behavior	Inspect semiannually	Replace parts as needed
Temperature monitors	No damage	Inspect visually semiannually	Replace parts as needed
Moisture meter	No damage	Inspect visually semiannually	Replace parts as needed
Anemometer	No damage; parts move freely	Inspect visually semiannually	Repair or replace parts as necessary
Manometer	Clean; no damage	Inspect semiannually; dissemble and clean yearly	Replace parts as needed
Barometer and humidity gauge	No damage	Inspect visually semiannually	Replace parts as needed

8.0 AUDITING PROCEDURES

This section outlines recommended audits for ensuring the quality of the Method 28 measurements. An audit is an independent assessment of the accuracy of data. Independence is achieved by having the audit made by an operator other than the one conducting the routine measurements and by using audit standards and equipment different from those routinely used in monitoring. The auditing procedures should include a performance evaluation of the individual measurement system components, as well as an inspection of the total measurement system. An activity matrix summarizing the auditing procedures is presented in Table 8.1 at the end of this section. Although not part of the auditing procedures, routine quality control checks by a testing team are also necessary in generation of quality data.

8.1 Performance Audits

Performance audits quantitatively evaluate the quality of data produced by the total measurement system. The components of the measurement system that require audits include the platform scale and fuel moisture meter, as well as the methods for determining usable firebox volume and for processing data. An audit should be performed for each of these system components once during every certification test. The auditing procedures for each of these components follow.

8.1.1 Platform Scale - An independent audit of the platform scale should be performed with at least three standard weights that have been certified by the National Bureau of Standards. The audit should be performed with the wood heater and flue pipe assembly installed on the platform scale to determine if the scale is capable of accurately measuring the weight changes of the test fuel. The flue pipe assembly should not interfere with the performance of the platform scale. The three standard weights should span the weight changes of the test fuel during a test run. One of the standard weights should be approximately the weight of a full test load, the second should be approximately half the weight of a test load, and the third should be 1 kg. The audit should be performed either during the pretest burn period or immediately following the test run. During the audit, the platform surface temperature should not exceed the maximum recommended operating temperature of the platform scale.

8.1.2 Fuel Moisture Meter - The manufacturer's recommended calibration procedures are acceptable. In addition, the accuracy of the fuel moisture meter can be ensured by comparing the meter's readings to the amount of moisture that evaporates during oven drying. This comparison is done by first measuring the moisture content of three test fuel pieces with the moisture meter. Then the same three test fuel pieces should be oven dried and the moisture content determined by using the procedures outlined in Section 2.8.3. The results of the independent measurements should be compared and, if there is any disagreement, the moisture meter should be recalibrated.

8.1.3 Firebox Volume Measurement - The audit of the firebox volume measurement consists of an independent determination of the usable firebox volume. It is recommended that the audit be performed before emissions sampling to ensure that the weight of the test fuel load is correct. When performing the audit, the auditor should measure the firebox dimensions and determine the usable firebox volume independently of the testing team by using the procedures in Section 3.1. The results of the audit should be compared to the firebox volume calculated by the testing team. If the audit yields a disagreement greater than 5%, the firebox volume should be determined again by using common dimensions and calculations as agreed upon by both the auditor and testing team.

8.1.4 Data Processing - The data recorded on the field and laboratory forms should be inspected for unusual data points or errors. A complete set of calculations should be performed by the auditor to ensure that burn rates and weighted emissions rates were determined correctly. If computer software is used to perform calculations, sample data should be entered into the programs. Results based on the sample data should then be hand calculated and compared to the results generated by the computer. If disagreement results, the software should be corrected as necessary.

8.2 Systems Audit

A systems audit is an on-site qualitative inspection and review of the total measurement system (process measurement, data processing, etc.). When a new laboratory is set up, a systems audit is recommended for each certification test until the measurement procedures become familiar to the operator.

TABLE 8.1. ACTIVITY MATRIX FOR AUDITING PROCEDURES

Measurement System Component	Auditing Procedures
Platform Scale	Measure the accuracy of the platform scale by using three different NBS standard weights.
Fuel Moisture Meter	According to manufacturer's instructions, or compare the fuel moisture meter readings of three test fuel pieces to the amount of moisture that evaporates during oven drying of the fuel.
Method of Determining Usable Firebox Volume	Measure firebox dimensions and calculate usable firebox volume independently. These should agree to within 5%.
Method of Processing Data	Inspect field and laboratory data sheets, and calculate burn rate and weighted emission rates independently.
Overall Systems Check	Inspect and review all on-site process measurement activities and data processing procedures.

9.0 REFERENCE METHOD

Method 28—Certification and Auditing of Wood Heaters

1. Applicability and Principle

1.1 Applicability. This method is applicable for the certification and auditing of wood heaters. This method describes the test facility, test fuel charge, and wood heater operation as well as procedures for determining burn rates and particulate emission rates and for reducing data.

1.2 Principle. Particulate matter emissions are measured from a wood heater burning a prepared test fuel crib in a test facility maintained at a set of prescribed conditions.

2. Definitions

2.1 Burn Rate. The rate at which test fuel is consumed in a wood heater. Measured in kilograms of wood (dry basis) per hour (kg/hr).

2.2 Certification or Audit Test. A series of at least four test runs conducted for certification or audit purposes that meets the burn rate specifications in Section 5.

2.3 Firebox. The chamber in the wood heater in which the test fuel charge is placed and combusted.

2.4 Secondary Air Supply. An air supply that introduces air to the wood heater such that the burn rate is not altered by more than 25 percent when the secondary air supply is adjusted during the test run. The wood heater manufacturer can document this through design drawings that show the secondary air is introduced only into a mixing chamber or secondary chamber outside the firebox.

2.5 Test Facility. The area in which the wood heater is installed, operated, and sampled for emissions.

2.6 Test Fuel Charge. The collection of test fuel pieces placed in the wood heater at the start of the emission test run.

2.7 Test Fuel Crib. The arrangement of the test fuel charge with the proper spacing requirements between adjacent fuel pieces.

2.8 Test Fuel Loading Density. The weight of the as-fired test fuel charge per unit volume of usable firebox.

2.9 Test Fuel Piece. The 2 x 4 or 4 x 4 wood piece cut to the length required for the test fuel charge and used to construct the test fuel crib.

2.10 Test Run. An individual emission test which encompasses the time required to consume the mass of the test fuel charge.

2.11 Usable Firebox Volume. The volume of the firebox determined using the following definitions:

2.11.1 Height. The vertical distance extending above the loading door, if fuel could reasonably occupy that space, but not more than 2 inches above the top (peak height) of the loading door, to the floor of the firebox (i.e., below a permanent grate) if the grate allows a 1-inch diameter piece of wood to pass through the grate, or, if not, to the top of the grate. Firebox height is not necessarily uniform but must account for variations caused by internal baffles, air channels, or other permanent obstructions.

2.11.2 Length. The longest horizontal fire chamber dimension that is parallel to a wall of the chamber.

2.11.3 Width. The shortest horizontal fire chamber dimension that is parallel to a wall of the chamber.

2.12 Wood Heater. An enclosed, woodburning appliance capable of and intended for space heating or domestic water heating, as defined in the applicable regulation.

2.13 Pellet Burning Wood Heater. A wood heater which meets the following criteria: (1) The manufacturer makes no reference to burning cord wood in advertising or other literature, (2) the unit is safety listed for pellet fuel only, (3) the unit operating and instruction manual must state that the use of cordwood is prohibited by law, and (4) the unit must be manufactured and sold including the hopper and auger combination as integral parts.

3. Apparatus

3.1 Insulated Solid Pack Chimney. For installation of wood heaters. Solid pack insulated chimneys shall have a minimum of 2.5 cm (1 in.) solid pack insulating material surrounding the entire flue and possess a label demonstrating conformance to U.L. Standard 103 (incorporated by reference. See § 60.17).

3.2 Platform Scale and Monitor. For monitoring of fuel load weight change. The scale shall be capable of measuring weight to within 0.05 kg (0.1 lb) or 1 percent of the initial test fuel charge weight, whichever is greater.

3.3 Wood Heater Temperature Monitors. Seven, each capable of measuring temperature to within 1.5 percent of expected absolute temperatures.

3.4 Test Facility Temperature Monitor. A thermocouple located centrally in a vertically oriented 150 mm (6 in.) long, 50 mm (2 in.) diameter pipe shield that is open at both ends, capable of measuring temperature to within 1.5 percent of expected temperatures.

3.5 Balance (optional). Balance capable of weighing the test fuel charge to within 0.05 kg (0.1 1b).

3.6 Moisture Meter. Calibrated electrical resistance meter for measuring test fuel moisture to within 1 percent moisture content.

3.7 Anemometer. Device capable of detecting air velocities less than 0.10 m/sec (20 ft/min), for measuring air velocities near the test appliance.

3.8 Barometer. Mercury, aneroid or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg).

3.9 Draft Gauge. Electromanometer or other device for the determination of flue draft or static pressure readable to within 0.50 Pa (0.002 in. H_2O).

3.10 Humidity Gauge. Psychrometer or hygrometer for measuring room humidity.

3.11 Sampling Methods. Use particulate emission measurement Method 5G or Method 5H to determine particulate concentrations, gas flow rates, and particulate emission rates.

4. Test Facility, Test Fuel Properties, and Test Fuel Charge Specifications

4.1 Test Facility.

4.1.1 Wood Heater Flue. Steel flue pipe extending to 2.6±0.15 m (8.5±0.5 ft) above the top of the platform scale, and above this level, insulated solid pack type chimney extending to 4.6+0.3 m (15±1 ft) above the platform scale, and of the size specified by the wood heater manufacturer. This applies to both freestanding and insert type wood heaters.

Other chimney types (e.g., solid pack insulated pipe) may be used in place of the steel flue pipe if the wood heater manufacturer's written appliance specifications require such chimney for home installation (e.g., zero clearance wood heater inserts). Such alternative chimney or flue pipe must remain and be sealed with the wood heater following the certification test.

4.1.2 Test Facility Conditions. The test facility temperature shall be maintained between 18 and 32 °C (65 and 90 °F) during each test run.

Air velocities within 0.6 m (2 ft) of the test appliance and exhaust system shall be less than 0.25 m/sec (50 ft/min) without fire in the unit.

The flue shall discharge into the same space or into a space freely communicating with the test facility. Any hood or similar device used to vent combustion products shall not induce a draft greater than 1.25 Pa (0.005 in. H_2O) on the wood heater measured when the wood heater is not operating.

For test facilities with artificially induced barometric pressures (e.g., pressurized chambers), the barometric pressure in the test facility shall not exceed 1.033 mb (30.5 in. Hg) during any test run.

4.2 Test Fuel Properties. The test fuel shall conform to the following requirements:

4.2.1 Fuel Species. Untreated, air-dried, Douglas fir lumber. Kiln-dried lumber is not permitted. The lumber shall be certified C grade (standard) or better Douglas fir by a lumber grader at the mill of origin as specified in the West Coast Lumber Inspection Bureau standard No. 16 (incorporated by reference. See § 60.17).

4.2.2 Fuel Moisture. The test fuel shall have a moisture content range between 16 to 20 percent on a wet basis (19 to 25 percent dry basis).

Addition of moisture to previously dried wood is not allowed. It is recommended that the test fuel be stored in a temperature and humidity-controlled room.

4.2.3 Fuel Temperature. The test fuel shall be at the test facility temperature 18 to 32 °C (65 to 90 °F).

4.3 Test Fuel Charge Specifications.

4.3.1 Fuel Dimensions. The dimensions of each test fuel piece shall conform to the nominal measurements of 2 x 4 and 4 x 4 lumber. Each piece of test fuel (not including spacers) shall be of equal length, except as necessary to meet requirements in Section 6.2.5, and shall closely approximate ⅚ the dimensions of the length of the usable firebox. The fuel piece dimensions shall be determined in relation to the appliance's firebox volume according to guidelines listed below:

4.3.1.1 If the usable firebox volume is less than or equal to 0.043 m^3 (1.5 ft^3), use 2 x 4 lumber.

4.3.1.2 If the usable firebox volume is greater than 0.043 m^3 (1.5 ft^3) and less than or equal to 0.085 m^3 (3.0 ft^3), use 2 x 4 and 4 x 4 lumber. About half the weight of the test fuel charge shall be 2 x 4 lumber, and the remainder shall be 4 x 4 lumber.

4.3.1.3 If the usable firebox volume is greater than 0.085 m³ (3.0 ft³), use 4 x 4 lumber.

4.3.2 Test Fuel Spacers. Air-dried, Douglas fir lumber meeting the fuel properties in Section 4.2. The spacers shall be 130 x 40 x 20 mm (5 x 1.5 x 0.75 in.).

4.3.3 Test Fuel Charge Density. The test fuel charge density shall be 112 ± 11.2 kg/m³ (7 ± 0.7 lb/ft³) of usable firebox volume on a wet basis.

4.4 Wood Heater Thermal Equilibrium. The average of the wood heater surface temperatures at the end of the test run shall agree with the average surface temperature at the start of the test run to within 70 °C (125 F).

5. Burn Rate Criteria

5.1 Burn Rate Categories. One emission test run is required in each of the following burn rate categories:

Burn Rate Categories

(Average kg/hr, dry basis)

Category 1	Category 2	Category 3	Category 4
<0.80	0.80 to 1.25	1.25 to 1.90	Maximum burn rate.

5.1.1 Maximum Burn Rate. For Category 4, the wood heater shall be operated with the primary air supply inlet controls fully open (or, if thermostatically controlled, the thermostat shall be set at maximum heat output) during the entire test run, or the maximum burn rate setting specified by the manufacturer's written instructions.

5.1.2 Other Burn Rate Categories. For burn rates in Categories 1 through 3, the wood heater shall be operated with the primary air supply inlet control, or other mechanical control device, set at a predetermined position necessary to obtain the average burn rate required for the category.

5.2 Alternative Burn Rates for Burn Rate Categories 1 and 2. If a wood heater cannot be operated at a burn rate below 0.80 kg/hr, two test runs shall be conducted with burn rates within Category 2. If a wood heater cannot be operated at a burn rate below 1.25 kg/hr, the flue shall be dampered or the air supply otherwise controlled in order to achieve two test runs within Category 2.

Evidence that a wood heater cannot be operated at a burn rate less than 0.80 kg/hr shall include documentation of two or more attempts to operate the wood heater in burn rate Category 1 and fuel combustion has stopped, or results of two or more test runs demonstrating that the burn rates were greater than 0.80 kg/hr when the air supply controls were adjusted to the lowest possible position or settings. Stopped fuel combustion is evidenced when an elapsed time of 30 minutes or more has occurred without a measurable (< 0.05 kg (0.1 lb) or 1.0 percent, whichever is greater) weight change in the test fuel charge. See also Section 6.4.3. Report the evidence and the reasoning used to determine that a test in burn rate Category 1 cannot be achieved: for example, two attempts to operate at a burn rate of 0.4 kg/hr are not sufficient evidence that burn rate Category 1 cannot be achieved.

Note: After July 1, 1990, if a wood heater cannot be operated at a burn rate less than 0.80 kg/hr, at least one test run with an average burn rate of 1.00 kg/hr or less shall be conducted. Additionally, if flue dampering must be used to achieve burn rates below 1.25 kg/hr (or 1.0 kg/hr), results from a test run conducted at burn rates below 0.90 kg/hr need not be reported or included in the test run average provided that such results are replaced with results from a test run meeting the criteria above.

6. Procedures

6.1 Catalytic Combustor and Wood Heater Aging. The catalyst-equipped wood heater or a wood heater of any type shall be aged before the certification test begins. The aging procedure shall be conducted and documented by a testing laboratory accredited according to procedures in § 60.535 of 40 CFR Part 60.

6.1.1 Catalyst-equipped Wood Heater. Operate the catalyst-equipped wood heater using fuel described in Section 4.2 or cordwood with a moisture content between 15 and 25 percent on a wet basis. Operate the wood heater at a medium burn rate (Category 2 or 3) with a new catalytic combustor in place and in operation for at least 50 hours. Record and report hourly catalyst exit temperature data (Section 6.2.2) and the hours of operation.

6.1.2 Non-Catalyst Wood Heater. Operate the wood heater using the fuel described in Section 6.1.1 at a medium burn rate for at least 10 hours. Record and report the hours of operation.

6.2 Pretest Preparation. Record the test fuel charge dimensions and weights, and wood heater and catalyst descriptions as shown in the example in Figure 28-3.

6.2.1 Wood Heater Installation. Assemble the wood heater appliance and parts in conformance with the manufacturer's written installation instructions. Place the wood heater centrally on the platform scale and connect the wood heater to the flue described in Section 4.1.1. Clean the flue with an appropriately sized, wire chimney brush before each certification test.

6.2.2 Wood Heater Temperature Monitors. For catalyst-equipped wood heaters, locate a temperature monitor (optional) about 25 mm (1 in.) upstream of the catalyst at the centroid of the catalyst face area, and locate a temperature monitor (mandatory) that will indicate the catalyst exhaust temperature. This temperature monitor is centrally located within 25 mm (1 in.) downstream at the centroid of catalyst face area. Record these locations.

Locate wood heater surface temperature monitors at five locations on the wood heater firebox exterior surface. Position the temperature monitors centrally on the top surface, on two sidewall surfaces, and on the bottom and back surfaces. Position the monitor sensing tip on the firebox exterior surface inside of any heat shield, air circulation walls, or other wall or shield separated from the firebox exterior surface. Surface temperature locations for unusual design shapes (e.g., spherical, etc.) shall be positioned so that there are *four* surface temperature monitors in both the vertical and horizontal planes passing at right angles through the centroid of the firebox, not including the fuel loading door (total of five temperature monitors).

6.2.3 Test Facility Conditions. Locate the test facility temperature monitor on the horizontal plane that includes the primary air intake opening for the wood heater. Locate the temperature monitor 1 to 2 m (3 to 6 ft) from the front of the wood heater in the 90° sector in front of the wood heater.

Use an anemometer to measure the air velocity. Measure and record the room air velocity before the pretest ignition period (Section 6.3) and once immediately following the test run completion.

Measure and record the test facility's ambient relative humidity, barometric pressure, and temperature before and after each test run.

Measure and record the flue draft or static pressure in the flue at a location no greater than 0.3 m (1 ft) above the flue connector at the wood heater exhaust during the test run at the recording intervals (Section 6.4.2).

6.2.4 Wood Heater Firebox Volume. Determine the firebox volume using the definitions for height, width, and length in Section 2. Volume adjustments due to presence of firebrick and other permanent fixtures may be necessary. Adjust width and length dimensions to extend to the metal wall of the wood heater above the firebrick or permanent obstruction if the firebrick or obstruction extending the length of the side(s) or back wall extends less than one-third of the usable firebox height. Use the width or length dimensions inside the firebrick if the firebrick extends more than one-third of the usable firebox height. If a log retainer or grate is a permanent fixture and the manufacturer recommends that no fuel be placed outside the retainer, the area outside of the retainer is excluded from the firebox volume calculations.

In general, exclude the area above the ash lip if that area is less than 10 percent of the usable firebox volume. Otherwise, take into account consumer loading practices. For instance, if fuel is to be loaded front-to-back, an ash lip may be considered usable firebox volume.

Include areas adjacent to and above a baffle (up to two inches above the fuel loading opening) if four inches or more horizontal space exist between the edge of the baffle and a vertical obstruction (e.g., sidewalls or air channels).

6.2.5 Test Fuel Charge. Prepare the test fuel pieces in accordance with the specifications in Section 4.3. Determine the test fuel moisture content with a calibrated electrical resistance meter or other equivalent performance meter. (To convert moisture meter readings from the dry basis to the wet basis: (100)(percent dry reading) ÷ (100 + percent dry reading) = percent moisture wet basis.) Determine fuel moisture for each fuel piece (not including spacers) by averaging at least three moisture meter readings, one from each of three sides, measured parallel to the wood grain. Average all the readings for all the fuel pieces in the test fuel charge. If an electrical resistance type meter is used. penetration of insulated electrodes shall be one-fourth the thickness of the test fuel piece or 19 mm (0.75 in.). whichever is greater. Measure the moisture content within a 4-hour period prior to the test run. Determine the fuel temperature by measuring the temperature of the room where the wood has been stored for at least 24 hours prior to the moisture determination.

Attach the spacers to the test fuel pieces with uncoated. ungalvanized nails or staples as illustrated in Figure 28–1. Attachment of spacers to the top of the test fuel piece(s) on top of the test fuel charge is optional.

To avoid stacking difficulties. or when a whole number of test fuel pieces does not result. all piece lengths shall be adjusted uniformly to remain within the specified loading density. The shape of the test fuel crib shall be geometrically similar to the shape of the firebox volume without resorting to special angular or round cuts on the individual fuel pieces.

6.2.6 Sampling Method. Prepare the sampling equipment as defined by the selected method. Collect one particulate emission sample for each test run.

6.2.7 Secondary Air Adjustment Validation. If design drawings do not show the introductions of secondary air into a chamber outside the firebox (Section 2.4). conduct a separate test of the wood heater's secondary air supply. Operate the wood heater at a burn rate in Category 1 (Sections 5.1 or 5.2) with the secondary air supply operated following the manufacturer's written instructions. Start the secondary air validation test run as described in Section 6.4.1. except no emission sampling is necessary and burn rate data shall be recorded at 5-minute intervals.

After the start of the test run. operate the wood heater with the secondary air supply set as per the manufacturer's instructions. but with no adjustments to this setting. After 25 percent of the test fuel has been consumed. adjust the secondary air supply controls to another setting. as per the manufacturer.s instructions. Record the burn rate data (5-minute intervals) for 20 minutes following the air supply adjustment.

Adjust the air supply control(s) to the original position(s). operate at this condition for at least 20 minutes. and repeat the air supply adjustment procedure above. Repeat the procedure three times at equal intervals over the entire burn period as defined in Section 6.4. If the secondary air adjustment results in a burn rate change of more than an average of 25 percent between the 20-minute periods before and after the secondary adjustments. the secondary air supply shall be considered a primary air supply. and no adjustment to this air supply is allowed during the test run.

6.3 Pretest Ignition. Build a fire in the wood heater in accordance with the manufacturer's written instructions.

6.3.1 Pretest Fuel Charge. Crumpled newspaper loaded with kindling may be used to help ignite the pretest fuel. The pretest fuel. used to sustain the fire. shall meet the same fuel requirements prescribed in Section 4.2. The pretest fuel charge shall consist of whole 2 x 4's that are no less than 1/3 the length of the test fuel pieces. Pieces of 4 x 4 lumber in approximately the same weight ratio as for the test fuel charge may be added to the pretest fuel charge.

6.1.2 Wood Heater Operation and Adjustments. Set the air inlet supply controls at any position that will maintain combustion of the pretest fuel load. At least one hour before the start of the test run. set the air supply controls at the approximate positions necessary to achieve the burn rate desired for the test run. Adjustment of the air supply controls. fuel addition or subtractions. and coalbed raking shall be kept to a minimum but are allowed up to 15 minutes prior to the start of the test run. For the purposes of this method. coalbed raking is the use of a metal tool (poker) to stir coals. break burning fuel into smaller pieces. dislodge fuel pieces from positions of poor combustion. and check for the condition of uniform charcoalization. Record all adjustments made to the air supply controls. adjustments to and additions or subtractions of fuel. and any other changes to wood heater operations that occur during pretest ignition period. Record fuel weight data and wood heater temperature measurements at 10-minute intervals during the hour of the pretest ignition period preceding the start of the test run. During the 15-minute period prior to the start of the test run. the wood heater loading door shall not be open more than a total of 1 minute. Coalbed raking is the only adjustment allowed during this period.

Note: One purpose of the pretest ignition period is to achieve uniform charcoalization of the test fuel bed prior to loading the test fuel charge. Uniform charcoalization is a general condition of the test fuel bed evidenced by an absence of large pieces of burning wood in the coal bed and the remaining fuel pieces being brittle enough to be broken into smaller charcoal pieces with a metal poker. Manipulations to the fuel bed prior to the start of the test run should be done to achieve uniform charcoalization while maintaining the desired burn rate. In addition. some wood heaters (e.g.. high mass units) may require extended pretest burn time and fuel additions to reach an initial average surface temperature sufficient to meet the thermal equilibrium criteria in Section 4.4.

The weight of pretest fuel remaining at the start of the test run is determined as the difference between the weight of the wood heater with the remaining pretest fuel and the tare weight of the cleaned. dry wood heater with or without dry ash or sand added consistent with the manufacturer's instructions and the owner's manual. The tare weight of the wood heater must be determined with the wood heater (and ash. if added) in a dry condition.

6.4 Test Run. Complete a test run in each burn rate category. as follows:

6.4.1 Test Run Start. When the kindling and pretest fuel have been consumed to leave a fuel weight between 20 and 25 percent of the weight of the test fuel charge. record the weight of the fuel remaining and start the test run. Record and report any other criteria. in addition to those specified in this section. used to determine the moment of the test run start (e.g.. firebox or catalyst temperature). whether such criteria are specified by the wood heater manufacturer or the testing laboratory. Record all wood heater individual surface temperatures. catalyst temperatures. any initial sampling method measurement values. and begin the particulate emission sampling. Within 1 minute following the start of the test run. open the wood heater door. load the test fuel charge. and record the test fuel charge weight. Recording of average. rather than individual. surface temperatures is acceptable for tests conducted in accordance with § 60.533(o)(3)(i) of 40 CFR Part 60.

Position the fuel charge so that the spacers are parallel to the floor of the firebox. with the spacer edges abutting each other. If loading difficulties result. some fuel pieces may be placed on edge. If the usable firebox volume is between 0.043 and 0.085 m³ (1.5 and 3.0 ft³). alternate the piece sizes in vertical stacking layers to the extent possible. For example. place 2 x 4's on the bottom layer in direct contact with the coal bed and 4 x 4's on the next layer. etc. (See Figure 28–2). Position the fuel pieces parallel to each other and parallel to the longest wall of the firebox to the extent possible within the specifications in Section 6.2.5.

Load the test fuel in appliances having unusual or unconventional firebox design maintaining air space intervals between the test fuel pieces and in conformance with the manufacturer's written instructions. For any appliance that will not accommodate the loading arrangement specified in the paragraph above. the test facility personnel shall contact the Administrator for an alternative loading arrangement.

The wood heater door may remain open and the air supply controls adjusted up to five minutes after the start of the test run in order to make adjustments to the test fuel charge and to ensure ignition of the test fuel charge has occurred. Within the five minutes after the start of the test run. close the wood heater door and adjust the air supply controls to the position determined to produce the desired burn rate. No other adjustments to the air supply controls or the test fuel charge are allowed (except as specified in Sections 6.4.3 and 6.4.4) after the first five minutes of the test run. Record the length of time the wood heater door remains open. the adjustments to the air supply controls. and any other operational adjustments.

6.4.2 Data Recording. Record fuel weight data. wood heater individual surface and catalyst temperature measurements. other wood heater operational data (e.g.. draft). test facility temperature and sampling method data at 10-minute intervals (or more frequently at the option of the tester) as shown on example data sheet. Figure 28–4.

6.4.3 Test Fuel Charge Adjustment. The test fuel charge may be adjusted (i.e.. repositioned) once during a test run if more than 60 percent of the initial test fuel charge weight has been consumed and more than 10 minutes have elapsed without a measurable (< 0.05 kg (0.1 lb) or 1.0 percent. whichever is greater) weight change. The time used to make this adjustment shall be less than 15 seconds.

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6.4.4 Air Supply Adjustment. Secondary air supply controls may be adjusted once during the test run following the manufacturer's written instructions (see Section 6.2.7). No other air supply adjustments are allowed during the test run.

Recording of wood heater flue draft during the test run is optional for tests conducted in accordance with § 60.533(o)(3)(i) of 40 CFR Part 60.

6.4.5 Auxiliary Wood Heater Equipment Operation. Heat exchange blowers sold with the wood heater shall be operated during the test run following the manufacturer's written instructions. If no manufacturer's written instructions are available, operate the heat exchange blower in the "high" position. (Automatically operated blowers shall be operated as designed.) Shaker grates, by-pass controls, or other auxiliary equipment may be adjusted only one time during the test run following the manufacturer's written instructions.

Record all adjustments on a wood heater operational written record.

Note: If the wood heater is sold with a heat exchange blower as an option, test the wood heater with the heat exchange blower operating as described in Sections 5 and 6 and report the results. As an alternative to repeating all test runs without the heat exchange blower operating, the tester may conduct one test run without the blower operating as described in Section 6.4.5 at a burn rate in Category 2 (Section 5.1). If the emission rate resulting from this test run without the blower operating is equal to or less than the emission rate plus 1.0 g/hr for the test run in burn rate Category 2 with the blower operating, the wood heater may be considered to have the same average emission rate with or without the blower operating. Additional test runs without the blower operating are unnecessary.

6.5 Consecutive Test Runs. Test runs on a wood heater may be conducted consecutively provided that a minimum one-hour interval occurs between test runs.

6.6 Additional Test Runs. The testing laboratory may conduct more than one test run in each of the burn rate categories specified in Section 5.1. If more than one test run is conducted at a specified burn rate, the results from at least two-thirds of the test runs in that burn rate category shall be used in calculating the weighted average emission rate (see Section 8.1). The measurement data and results of all test runs shall be reported regardless of which values are used in calculating the weighted average emission rate (see Note: in Section 5.2).

6.7 Pellet Burning Heaters. Certification testing procedures for pellet burning wood heaters are based on the procedures in this method. The differences in the procedures from the sections in Method 28 are as follows:

6.7.1 Test Fuel Properties. The test fuel shall be all wood pellets with a moisture content no greater than 20 percent on a wet basis (25 percent on a dry basis). Determine the wood moisture content with either ASTM–D2016–74(82)(Method A) or ASTM D4442–84, (incorporated by reference. See Section 60.17).

6.7.2 Test Fuel Charge Specifications. The test fuel charge size shall be as per the manufacturer's written instructions for maintaining the desired burn rate.

6.7.3 Wood Heater Firebox Volume. The firebox volume need not be measured or determined for establishing the test fuel charge size. The firebox dimensions and other heater specifications needed to identify the heater for certification purposes shall be reported.

6.7.4 Heater Installation. Arrange the heater with the fuel supply hopper on the platform scale as described in Section 6.2.1.

6.7.5 Pretest Ignition. Start a fire in the heater as directed by the manufacturer's written instructions, and adjust the heater controls to achieve the desired burn rate. Operate the heater at the desired burn rate for at least 1 hour before the start of the test run.

6.7.6 Sampling Method. Method 5G or 5H shall be used for the certification testing of pellet burners. Prepare the sampling equipment as described in Method 5G or 5H. Collect one particulate emission sample for each test run.

6.7.7 Test Run. Complete a test run in each burn rate category as follows:

6.7.7.1 Test Run Start. When the wood heater has operated for at least 1 hour at the desired burn rate, add fuel to the supply hopper as necessary to complete the test run, record the weight of the fuel in the supply hopper (the wood heater weight), and start the test run. Add no additional fuel to the hopper during the test run.

Record all the wood heater surface temperatures, the initial sampling method measurement values, the time at the start of the test, and begin the emission sampling. Make no adjustments to the wood heater air supply or wood supply rate during the test run.

6.7.7.2 Data Recording. Record the fuel (wood heater) weight data, wood heater temperature and operational data, and emission sampling data as described in Section 6.4.2.

6.7.7.3 Test Run Completion. Continue emission sampling and wood heater operation for 2 hours. At the end of the test run, stop the particulate sampling, and record the final fuel weight, the run time, and all final measurement values.

6.7.8 Calculations. Determine the burn rate using the difference between the initial and final fuel (wood heater) weights and the procedures described in Section 8.3. Complete the other calculations as described in Section 8.

7. Calibrations

7.1 Platform Scale. Perform a multipoint calibration (at least five points spanning the operational range) of the platform scale before its initial use. The scale manufacturer's calibration results are sufficient for this purpose. Before each certification test, audit the scale with the wood heater in place by weighing at least one calibration weight (Class F) that corresponds to 20 percent to 80 percent of the expected test fuel charge weight. If the scale cannot reproduce the value of the calibration weight within 0.05 kg (0.1 lbs) or 1 percent of the expected test fuel charge weight, whichever is greater, recalibrate the scale before use with at least five calibration weights spanning the operational range of the scale.

7.2 Balance (optional). Calibrate as described in Section 7.1.

7.3 Temperature Monitor. Calibrate as in Method 2, Section 4.3, before the first certification test and semiannually thereafter.

7.4 Moisture Meter. Calibrate as per the manufacturer's instructions before each certification test.

7.5 Anemometer. Calibrate the anemometer as specified by the manufacturer's instructions before the first certification test and semiannually thereafter.

7.6 Barometer. Calibrate against a mercury barometer before the first certification test and semiannually thereafter.

7.7 Draft Gauge. Calibrate as per the manufacturer's instructions; a liquid manometer does not require calibration.

7.8 Humidity Gauge. Calibrate as per the manufacturer's instructions before the first certification test and semiannually thereafter.

8. Calculations and Reporting

Carry out calculations retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation.

8.1 Weighted Average Emission Rate.

$$E_w = \frac{\sum_{i=1}^{n} (K_i E_i)}{\sum_{i=1}^{n} K_i} \qquad \text{Eq. 28–1}$$

where:

E_w = Weighted average emission rate, g/hr;

E_i = Emission rate for test run, i, from Method 5G or 5H, g/hr;

K_i = Test run weighting factor = $P_{i+1}\ P_{i-1}$;

n = Total number of test runs;

P_i = Probability for burn rate during test run, i, obtained from Table 28–1. Use linear interpolation to determine probability values for burn rates between those listed on the table.

Note: P_0 always equals 0, $P_{(n+1)}$ always equals 1, P_1 corresponds to the probability of the lowest recorded burn rate, P_2 corresponds to the probability of the next lowest burn rate, etc. An example calculation is shown on Figure 28–5.

8.2 Average Wood Heater Surface Temperatures. Calculate the average of the wood heater surface temperatures for the start of the test run (Section 6.3.1) and for the test run completion (Section 6.3.6). If the two average temperatures do not agree within 70°C (125°F), report the test run results, but do not include the test run results in the test average. Replace such test run results with results from another test run in the same burn rate category.

8.3 Burn Rate.

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$$BR = \frac{60\ W_{wd}}{\theta}\ \frac{100\%M_{w}}{100} \qquad \text{Eq. 28-2}$$

Where:

BR = Dry wood burn rate, kg/hr (lb/hr)
W_{wd} = Total mass of wood burned during the test run, kg (lb)
θ - Total time of test run, min.
$\%M_{w}$ = Average moisture in test fuel charge, wet basis, percent.

8.4 Reporting Criteria. Submit both raw and reduced test data for wood heater tests. Specific reporting requirements are as follows:

8.4.1 Wood Heater Identification. Report wood heater identification information. An example data form is shown on Figure 28-4.

8.4.2 Test Facility Information. Report test facility temperature, air velocity, and humidity information. An example data form is shown on Figure 28-4.

8.4.3 Test Equipment Calibration and Audit Information. Report calibration and audit results for the platform scale, test fuel balance, test fuel moisture meter, and sampling equipment including volume metering systems and gaseous analyzers.

8.4.4 Pretest Procedure Description. Report all pretest procedures including pretest fuel weight, burn rates, wood heater temperatures, and air supply settings. An example data form is shown on Figure 28-4.

8.4.5 Particulate Emission Data. Report a summary of test results for all test runs and the weighted average emission rate. Submit copies of all data sheets and other records collected during the testing. Submit examples of all calculations.

8.4.6 Suggested Test Report Format.

a. Introduction

1. Purpose of test—certification, audit, efficiency, research and development.

2. Wood heater identification—manufacturer, model number, catalytic/noncatalytic, options.

3. Laboratory—name, location (altitude), participants.

4. Test information—date wood heater received, date of tests, sampling methods used, number of test runs.

b. Summary and Discussion of Results

1. Table of results (in order of increasing burn rate)—test run number, burn rate, particulate emission rate, efficiency (if determined), averages (indicate which test runs are used).

2. Summary of other data—test facility conditions, surface temperature averages, catalyst temperature averages, pretest fuel weights, test fuel charge weights, run times.

3. Discussion—Burn rate categories achieved, test run result selection, specific test run problems and solutions.

c. Process Description

1. Wood heater dimensions—volume, height, width, lengths (or other linear dimensions), weight, volume adjustments.

2. Firebox configuration—air supply locations and operation, air supply introduction location, refractory location and dimensions, catalyst location, baffle and by-pass location and operation (include line drawings or photographs).

3. Process operation during test—air supply settings and adjustments, fuel bed adjustments, draft.

4. Test fuel—test fuel properties (moisture and temperature), test fuel crib description (include line drawing or photograph), test fuel charge density.

d. Sampling Locations

Describe sampling location relative to wood heater. Include drawing or photograph.

e. Sampling and Analytical Procedures

1. Sampling methods—brief reference to operational and sampling procedures and optional and alternative procedures used.

2. Analytical methods—brief description of sample recovery and analysis procedures.

f. Quality Control and Assurance Procedures and Results

1. Calibration procedures and results—certification procedures, sampling and analysis procedures.

2. Test method quality control procedures—leak-checks, volume meter checks, stratification (velocity) checks, proportionality results.

Appendices

1. Results and Example Calculations. Complete summary tables and accompanying examples of all calculations.

2. Raw Data. Copies of all uncorrected data sheets for sampling measurements, temperature records and sample recovery data. Copies of all pretest burn rate and wood heater temperature data.

3. Sampling and Analytical Procedures. Detailed description of procedures followed by laboratory personnel in conducting the certification test, emphasizing particularly parts of the procedures differing from the methods (e.g., approved alternatives).

4. Calibration Results. Summary of all calibrations, checks, and audits pertinent to certification test results with dates.

5. Participants. Test personnel, manufacturer representatives, and regulatory observers.

6. Sampling And Operation Records. Copies of uncorrected records of activities not included on raw data sheets (e.g., wood heater door open times and durations).

7. Additional Information. Wood heater manufacturer's written instructions for operation during the certification test.

9. Bibliography

1. Oregon Department of Environmental Quality Standard Method for Measuring the Emissions and Efficiencies of Woodstoves, June 8, 1984. Pursuant to Oregon Administrative Rules Chapter 340, Division 21.

2. American Society for Testing Materials. Proposed Test Methods for Heating Performance and Emissions of Residential Wood-Fired Closed Combustion-Chamber Heating Appliances. E-6 Proposal P 180. August, 1986.

3. Radian Corporation. OMNI Environmental Services, Inc., Cumulative Probability for a Given Burn Rate Based on Data Generated in the CONEG and BPA Studies. Package of materials submitted to the Fifth Session of the Regulatory Negotiation Committee, July 16-17, 1986.

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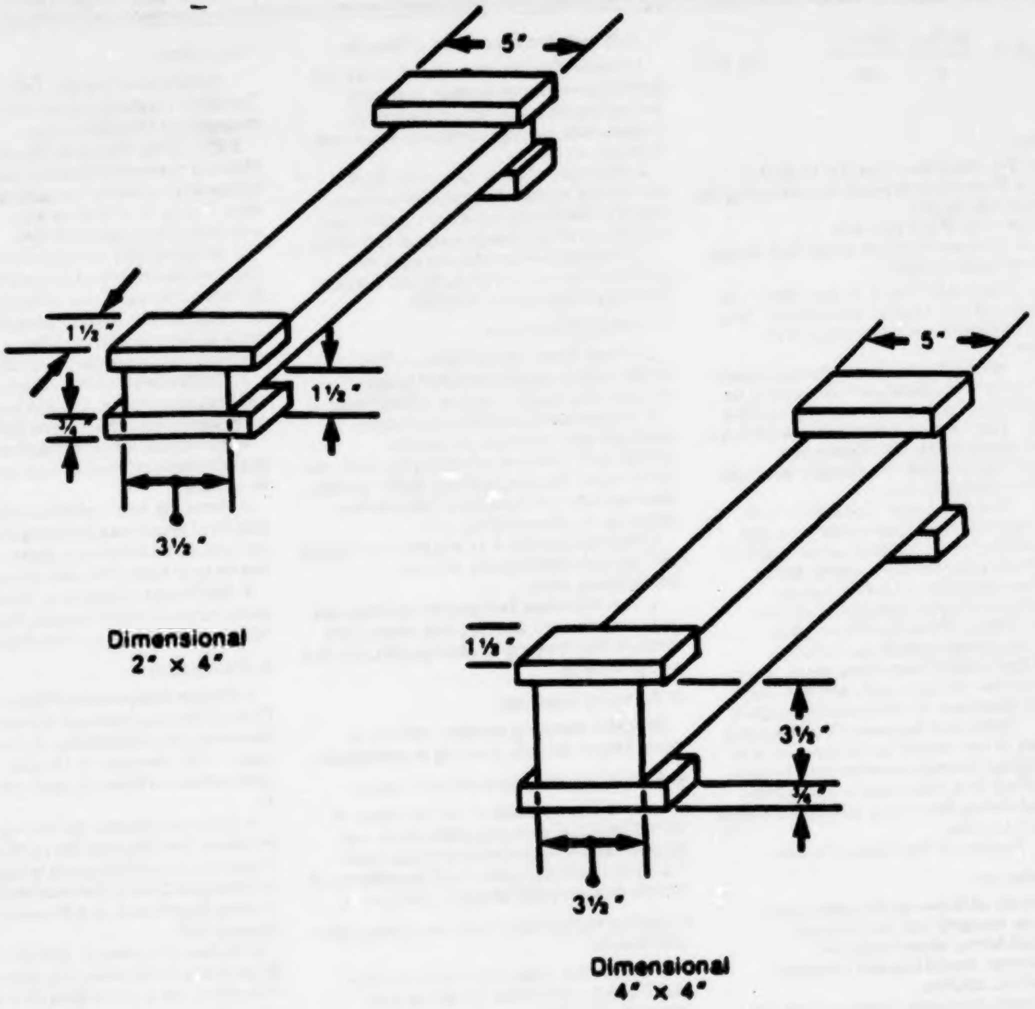
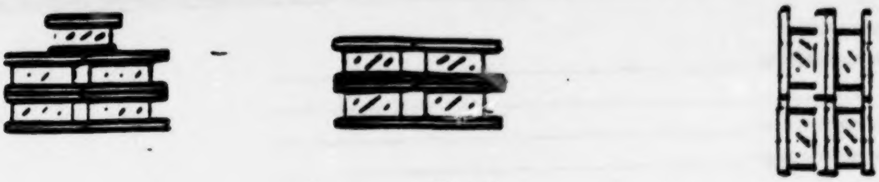

5"
1½"
1½"
¾"
3½"
5"
1½"
3½"
¾"
3½"

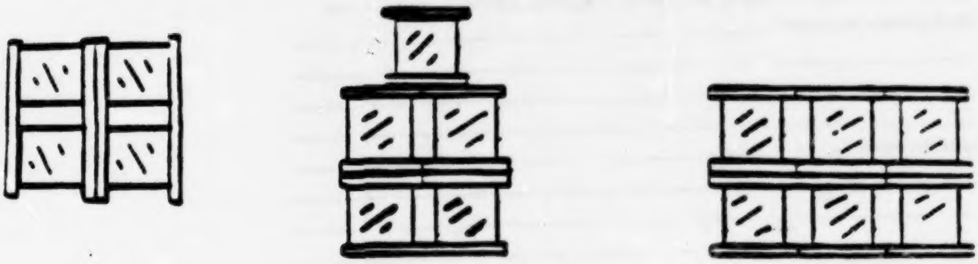
Dimensional
2" × 4"

Dimensional
4" × 4"

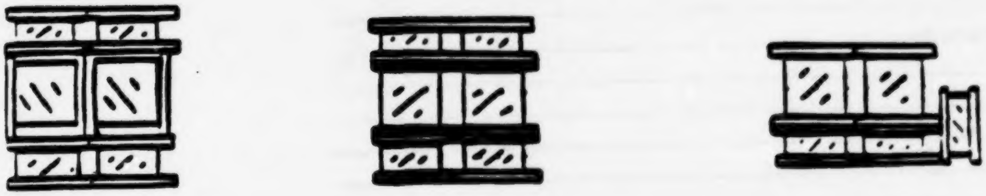
Figure 28-1. Test fuel spacer dimensions.



2 × 4



4 × 4



2 × 4 and 4 × 4

Figure 28 - 2. Test fuel crib arrangements

Appliance Identification

Appliance Manufacturer ______________________

Address ______________________

Agent and phone number ______________________

Name and Model number ______________________

Weight ______________________

Serial number ____________

Design : Catalytic ________ Noncatalytic ________

Insert ________ Freestanding ________

Woodheater Description : (Attach figure showing air supplies and firebox configuration)

Materials of construction : ______________________

Air Introduction System : ______________________

Combustion Control Mechanisms : ______________________

Internal Baffles : ______________________

Other Features : ______________________

Catalyst Specifications

Manufacturer ______________

Serial Number ______________

Age ______________ (Hours)

Dimensions ______________ (in.)

Firebox Dimensions :

Volume ______________ (ft³)

Length ______________ (in.)

Width ______________ (in.)

Height ______________ (in.)

Adjustments (Describe) ______________ (in.)

Test Fuel Information
(For each Test Run)

Weight of Test Charge ______________ (lb)

Number of 2 × 4's ______________

Number of 4 × 4's ______________

Length of test pieces ______________ (in.)

Fuel Grade (Certification) ______________

Fuel Moisture Content ______________ (%)

Diagram or Photograph of Test Fuel Crib

Figure 28-3. Wood Heater and Test Fuel Information.

Sheet ______ **of** ______

Date ________________

Operator ________________

Sampling Method ________________

Wood Heater Information

Manufacturer ____________

Model ____________

Primary Air Setting ____________

Secondary Air Setting _______

Thermostat Setting ____________

Other Settings ____________

Test Run Information

Test Run No. ____________________

Burn Rate ____________________

Room Temperature before/after ____/____

Barometric Pressure before/after ____/____

Relative Humidity before/after ____/____

Room Air Velocity before/after ____/____

Surface Temp Average Pretest _____ **end** _____

Test Run Time (minutes)	Test Fuel Scale Reading (lb)	Surface Temperature					Catalyst Temperature		Flue Draft (in. H_2O)
							Inlet (°F)	Outlet (°F)	
(Pretest Period)									
(Test Run Start)									

88/0462R

Figure 28 - 4. Test run wood heater operation data sheet

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FIGURE 28-5.—EXAMPLE CALCULATION OF WEIGHTED AVERAGE EMISSION RATE

Burn rate category	Test number	Burn rate (Dry-kg/hr)	Emissions (g/hr)
1	1	0.65	5.0
2[1]	2	0.85	6.7
2	3	0.90	4.7
2	4	1.00	5.3
3	5	1.45	3.8
4	6	2.00	5.1

[1] As permitted in Section 6.6, this test run may be omitted from the calculation of the weighted average emission rate because three runs were conducted for this burn rate category.

Test number	Burn rate	P_i	E_i	K_i
1	0.65	0.121	5.0	0.300
2	0.90	0.300	4.7	0.259
3	1.00	0.380	5.3	0.422
4	1.45	0.722	3.8	0.532
5	2.00	0.912	5.1	0.278

$K_1 = P_2 - P_0 = 0.300 - 0 = 0.300$
$K_2 = P_3 - P_1 = 0.380 - 0.121 = 0.259$
$K_3 = P_4 - P_2 = 0.722 - 0.300 = 0.422$
$K_4 = P_5 - P_3 = 0.912 - 0.380 = 0.532$
$K_5 = P_6 - P_4 = 1 - 0.722 = 0.278$

$$\sum_{i=1}^{n} K_i = 0.300 + 0.259 + 0.422 + 0.532 + 0.278$$

$$\sum_{i=1}^{n} = 1.791$$

$$E_w = \frac{\sum_{i=1}^{n} (K_i E_i)}{\sum_{i=1}^{n} K_i}$$

E_w equals (0.3)(5.0) + (0.259)(4.7) + (0.422)(5.3) + (0.532)(3.8) + (0.278)(5.1) divided by 1.791

E_w = 4.69 g/hr.

TABLE 28-1.—BURN RATE WEIGHTED PROBABILITIES FOR CALCULATING WEIGHTED AVERAGE EMISSION RATES

Burn rate (kg/hr-dry)	Cumulative Probability (P)
0.00	0.000
0.05	0.002
0.10	0.007
0.15	0.012
0.20	0.016
0.25	0.021
0.30	0.028
0.35	0.033
0.40	0.041
0.45	0.054
0.50	0.066
0.55	0.086
0.60	0.100
0.65	0.121
0.70	0.150
0.75	0.185
0.80	0.220
0.85	0.254
0.90	0.300
0.95	0.328
1.00	0.380
1.05	0.407
1.10	0.460
1.15	0.490
1.20	0.550
1.25	0.572
1.30	0.620
1.35	0.654
1.40	0.686
1.45	0.722
1.50	0.750
1.55	0.779
1.60	0.800
1.65	0.825
1.70	0.840
1.75	0.857
1.80	0.875
1.85	0.882
1.90	0.895
1.95	0.906
2.00	0.912
2.05	0.920
2.10	0.925
2.15	0.932
2.20	0.936
2.25	0.940
2.30	0.945
2.35	0.951
2.40	0.956

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TABLE 28-1.—BURN RATE WEIGHTED PROBABILITIES FOR CALCULATING WEIGHTED AVERAGE EMISSION RATES—Continued

Burn rate (kg/hr-dry)	Cumulative Probability (P)
2.45	0.959
2.50	0.964
2.55	0.968
2.60	0.972
2.65	0.975
2.70	0.977
2.75	0.979
2.80	0.980
2.85	0.981
2.90	0.982
2.95	0.984
3.00	0.984
3.05	0.985
3.10	0.986
3.15	0.987
3.20	0.987
3.25	0.988
3.30	0.988
3.35	0.989
3.40	0.989
3.45	0.989
3.50	0.990
3.55	0.991
3.60	0.991
3.65	0.992
3.70	0.992
3.75	0.992
3.80	0.993
3.85	0.994
3.90	0.994
3.95	0.994
4.00	0.994
4.05	0.995
4.10	0.995
4.15	0.995
4.20	0.996
4.25	0.996
4.30	0.996
4.35	0.996
4.40	0.996
4.45	0.996
4.50	0.996
4.55	0.996
4.60	0.996
4.65	0.996
4.70	0.996
4.75	0.997
4.80	0.997
4.85	0.997
4.90	0.997
4.95	0.997
≥5.00	1.000

10.0 REFERENCES

1. Alberty, R. A. and F. Daniels. Physical Chemistry. New York, John Wiley and Sons, Inc. 1967. p. 125.

2. American Society for Testing and Materials. Standard Test Methods for Use and Calibration of Hand-held Moisture Meters. Designation: D4444-84. Philadelphia, Pennsylvania. 1984.

3. American Society for Testing and Materials. Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-base Materials. Designation: D4442-84. Philadelphia, Pennsylvania. 1984.

4. American Society for Testing and Materials. Standard Test Methods for Moisture Content of Wood. Designation: D2016-74. Philadelphia, Pennsylvania. 1983.

5. Thomas Register of American Manufacturers and Thomas Register Catalog File. New York, New York. Thomas Publishing Company. 1985.

6. Underwriters Laboratories, Inc. UL103: Standard for Chimneys, Factory-built Residential Type, and Building Heating Appliance. Chicago, Illinois. 1986.

11.0 DATA SHEETS

Blank data sheets are provided in the following pages for the convenience of the user of this manual to aid in calculations, record keeping, and data reporting. Use of these sheets will help ensure that all the calculations are done correctly and that the reporting of the test data is done correctly. It is suggested that the sheets be removed for duplication and then the originals returned to this manual for future reference. For discussion of the procedures for using the sheets, the reader is referred to the previous sections where example calculations or example applications are provided. An identification number is given in the lower right-hand corner of the blank sheet (e.g., Sheet M28-1.1 indicates that the sheet is used in Figure 1.1 in Section 1.0 of the Method 28 Quality Assurance Procedures).

Sheet	Title
1.1	Procurement Log
2.1	Platform Scale Calibration Sheet
2.2	Temperature Monitor Calibration Sheet
2.3	Semiannual Calibration Sheet
2.4	Moisture Meter Calibration Sheet
2.5	Summary Sheet: Instrument Calibration
3.11	Wood Heater and Catalyst Aging Documentation
3.12, 6.2	Secondary Air Validation Worksheet
3.13	Documentation of Test Fuel Measurements
3.16	Measurement of Test Facility Conditions
3.18	Checklist for Method 28 Pretest Procedures
4.1	Test Run Measurement Recording Sheet
4.2	Record of Wood Heater and Test Fuel Adjustments
6.1	Worksheet for Determining the Weighted Average Emission Rate

				Date				
Item Description	Quantity	Purchase Order Number	Vendor	Ordered	Received	Cost	Disposition	Comments

Figure 11.1. Sheet M28-1.1 - Procurement Log

Scale Model: Platform ________
Balance ________

Wood Heater Model ________
Weight of Test Fuel ________

Test Facility ________
Calibration Performed By ________
Date ________

Time	Test Run Number	Platform Temperature	Class F Calibration Weight (A)	Initial Scale Reading or Tare (B)	Final Scale Reading (C)	Measured Calibration Weight (D = C – B)	Difference (D minus A)	Action Taken

Figure 11.2. Sheet M28-2.1 - Scale Calibration Sheet

Temperature Monitor Type ______________
Identification Number ______________

Reference Temperature Monitor Type ______
Identification Number ______________

Readout Device ______________

Test Facility ______________
Calibration Performed By ______________
Date ______________

Ambient Temperature ______________
Barometric Pressure ______________

Reference Point Source [1]	Temperature of Reference Point [2]	Observed Temperature		Difference in Percent of Absolute Temperature [3]	Action Taken
		A Reference Temperature Monitor	B Temperature Monitor		

[1] Reference Points include ice-bath, boiling water, furnace, etc.

[2] Boiling Point H_2O in °C = 100 – .94 (29.92 – Barometric Pressure in in. Hg)
Boiling Point H_2O in °F = 212 – 1.69 (29.92 – Barometric Pressure in in. Hg)

[3] Difference in Percent Absolute = $\left(\frac{A - B}{A + 273}\right) \times 100$ for A and B in °C; $\left(\frac{A - B}{A + 460}\right) \times 100$, for A and B in °F

Figure 11.3. Sheet M28-2.2 - Temperature Monitor Calibration Sheet

Instrument to be Calibrated ____________
Model Number ____________

Test Facility ____________
Calibration Performed By ____________
Date of Calibration ____________

Method of Measurement	Reference Value (A)	Measured Value (B)	Difference (A minus B)	Acceptable Tolerance	Action Taken

Figure 11.4. Sheet M28-2.3 - Semiannual Calibration Sheet

Moisture Meter Type ______________________
Model Name ______________________
Model Number ______________________
Operating Temperature ______________________

Test Facility ______________________
Calibration Performed By ______________________
Date of Calibration ______________________

Reference Source	Moisture Content Equivalent of Reference Source (A)	Moisture Meter Reading (B)	Difference (Should be Within ± 1%) (A minus B)	Action Taken

Figure 11.5. Sheet M28-2.4 - Moisture Meter Calibration Sheet

Instrument Calibrated/ Identification Number	Date of Calibration	Reference Used	Reference Value	Measured Value	Difference	Acceptable Tolerance
Platform Scale						± 0.05 kg (0.1 lb)
Test Fuel Balance						± 0.05 kg (0.1 lb)
Moisture Meter						±1% Moisture Content
Temperature Monitors Thermocouple 1 Thermocouple 2 Thermocouple 3 Thermocouple 4 Thermocouple 5 Thermocouple 6 Thermocouple 7 Readout Device						± 1.5% Absolute Temperature (°K or °R)
Draft Gauge						0.5 Pa (0.002 in. H_2O)
Anemometer						± 0.1 m/sec (20 ft/min)
Barometer						± 2.5 mm Hg (0.1 in Hg)
Humidity Gauge						± 3% Relative Humidity

Figure 11.6. Sheet M28-2.5 - Summary Sheet: Instrument Calibration

Wood Heater and Catalyst Aging

1.0 Wood Heater Information

Wood Heater Manufacturer ____________________

Wood Heater Model ____________________

Catalyst Manufacturer ____________________

Aging Procedures Performed By ____________________

2.0 Aging Documentation

Date	Clock Time	Cumulative Aging Time (h)	Test Fuel Scale Reading (lb)	Catalyst Inlet Temperature (°F)	Catalyst Outlet Temperature (°F)
		0			
		1			
		2			
		3			
		4			
		5			
		6			
		7			
		8			
		9			
		10			
		11			
		12			
		13			
		14			
		15			
		16			
		17			
		18			
		19			
		20			
		21			
		22			
		23			
		24			
		25			
		26			
		27			
		28			
		29			
		30			

Figure 11.7. Sheet M28-3.11 - Example Data Sheet for Documenting Wood Heater and Catalyst Aging

Date	Clock Time	Cumulative Aging Time (h)	Test Fuel Scale Reading (lb)	Catalyst Inlet Temperature (°F)	Catalyst Outlet Temperature (°F)
		31			
		32			
		33			
		34			
		35			
		36			
		37			
		38			
		39			
		40			
		41			
		42			
		43			
		44			
		45			
		46			
		47			
		48			
		49			
		50			
		51			
		52			
		53			
		54			
		55			
		56			
		57			
		58			
		59			
		60			

Figure 11.7. Sheet M28-3.11 (Continued)

3.0 Fuel Additions

Date	Clock Time	Weight of Fuel Addition (lb)	Initials of Operator	Fuel Type: Cordwood or Dimensional

Figure 11.7. Sheet M28-3.11 (Continued)

Process Phase/Secondary Air Setting (original = setting for burn rate category 1) (adjusted = per manufacturer's instructions)	Step Time		Run Time (min)	Fuel Weight (lb)	20-Minute Average Burn Rate BR cycle step = $\frac{60 \times (W_{cycle,1} - W_{cycle,0})}{20 \times 2.205}$ (Wet kg/hr)	
Start of Run/original					= W_0 (Note: $W_{1,0}$ must be $< W_0 \times 0.75$)	
Cycle 1						
Step 1/adjusted	0				= $W_{1,0}$	
	5					BR_{11} = ________
	10					
	15					
Step 2/original	20	0			= $W_{1,1}$	
		5				BR_{12} = ________
		10				
		15				
Step 3/adjusted	0	20			= $W_{1,2}$	
	5					BR_{13} = ________
	10					
(Note: cycle 1, step 3 may overlap with cycle 2, step 1)	15					
	20				= $W_{1,3}$	
Cycle 2						
Step 1/adjusted	0				= $W_{2,0}$	
	5					BR_{21} = ________
	10					
	15					
Step 2/original	20	0			= $W_{2,1}$	
		5				BR_{22} = ________
		10				
		15				
Step 3/adjusted	0	20			= $W_{2,2}$	
	5					BR_{23} = ________
	10					
(Note: cycle 2, step 3 may overlap with cycle 3, step 1)	15					
	20				= $W_{2,3}$	
Cycle 3						
Step 1/adjusted	0				= $W_{3,0}$	
	5					BR_{31} = ________
	10					
	15					
Step 2/original	20	0			= $W_{3,1}$	
		5				BR_{32} = ________
		10				
		15				
Step 3/adjusted	0	20			= $W_{3,2}$	
	5					BR_{33} = ________
	10					
	15					
	20				= $W_{3,3}$	

(Note: All cycles must be complete. Use 2 cycles if necessary.)

$\overline{BR}_{1,3}$ = Avg(BR_{11}, BR_{13}, BR_{21}, BR_{23}, BR_{31}, BR_{33}) = ________

$\overline{BR}_2$ = Avg(BR_{12}, BR_{22}, BR_{32}) = ________

% Secondary Air Effect = $\frac{\overline{BR}_{1,3} - \overline{BR}_2}{\overline{BR}_{1,3}} \times 100$ = ________

Figure 11.8. Sheet M28-3.12 and Sheet M28-6.2 - Secondary Air Validation Worksheet

1.0 Wood Heater Test Fuel Information

Wood Heater Manufacturer ____________
Wood Heater Model ____________
Run Number ____________
Date ____________

2.0 Pretest Fuel Measurements

Piece	Length (inches)	Moisture Meter Readings (% Moisture Dry Basis)			Average % Moisture	Corrected Average*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

* Corrected for Moisture Meter Pin Type and Test Fuel Temperature

Figure 11.9. Sheet M28-3.13 - Documentation of Test Fuel Measurements

3.0 Test Fuel Measurements

2 × 4 Dimensional Lumber

Piece	Length (inches)	Moisture Meter Readings (% Moisture Dry Basis)			Average % Moisture	Corrected* Average
1						
2						
3						
4						
5						
6						
7						
8						

4 × 4 Dimensional Lumber

Piece	Length (inches)	Moisture Meter Readings (% Moisture Dry Basis)			Average % Moisture	Corrected* Average
1						
2						
3						
4						
5						
6						
7						
8						

Overall Test Fuel Moisture ________________

* Test Fuel Temperature ____________________
Correction Facor for Pin Type, and Fuel Temperature____________
Clock Time of Moisture Readings ________________

4.0 Test Fuel Crib

Weight of Test Charge____________ (lb)
Number of Spacers ____________
Diagram of Test Fuel Crib

Figure 11.9. Sheet M28-3.13 (Continued)

Stove Manufacturer: Stove Model:	Date of Test: Operator:	Run Number:
	Pretest Measurement	Post-Test Measurement
Barometric Pressure (in. Hg)		
Room Temperature (°F)		
Relative Humidity (%)		
Room Air Velocity (ft/min)		
Induced Draft (in. H_2O)		

Remarks:

Figure 11.10. Sheet M28-3.16 - Measurement of Test Facility Conditions

Activity	Acceptable Yes	 No
Measurement of Firebox Volume		
1. Firebox dimensions measured from actual wood heater to be tested?	____	____
2. Firebox dimensions checked against engineering drawings?	____	____
3. Firebox volume calculated?	____	____
4. Volume determination documented including calculations, illustrations, and volume adjustments?	____	____
5. Volume determination independently calculated and confirmed?	____	____
Wood Heater Installation		
6. Flue pipe cleaned and assembled leak-free?	____	____
7. Flue pipe and solid pack chimney installed to allow unobstructive vertical scale movement?	____	____
8. Induced draft measured and adjusted to less than 0.005 in. H_2O?	____	____
9. Flue pipe sampling ports meet location criteria?	____	____
General Comments		

Figure 11.11. Sheet M28-3.18 - Checklist for Method 28 Pretest Procedures

Activity	Acceptable	
	Yes	No
Wood Heater Installation (Continued)		
10. Calibrated surface temperature monitors installed on top, two sides, bottom, and back of wood heater?	_____	_____
11. Calibrated temperature monitor installed approximately 1 in. downstream of catalyst?	_____	_____
Apparatus Check and Calibrations		
12. Calibration records checked and verified for surface temperature and catalyst temperature monitors?	_____	_____
13. Calibration records checked and verified for platform scale?	_____	_____
14. Calibration records checked and verified for optional fuel balance?	_____	_____
15. Platform scale single-point calibration checked and acceptable?	_____	_____
16. Moisture meter calibration performed and recorded?	_____	_____

General Comments

Figure 11.11. Sheet M28-3.18 (Continued)

Activity	Acceptable	
	Yes	No
Apparatus Check and Calibrations (Continued)		
17. Calibration records checked and verified for anemometer?		
18. Calibration records checked and verified for barometer?		
19. Calibration records checked and verified for relative humidity gauge?		
20. Calibration records checked and verified for draft gauge?		
21. Calibration records checked and verified for temperature monitors?		
Catalytic Combustor and Wood Heater Aging		
22. Fuel specifications used for wood heater and catalyst aging documented?		
23. Catalyst temperatures recorded during aging procedures?		
24. Catalyst temperatures greater than 450°F for a minimum of 50 hours?		
25. Documentation demonstrating noncatalyst heater aging for a minimum of 10 hours?		

General Comments

Figure 11.11. Sheet M28-3.18 (Continued)

Activity	Acceptable Yes	 No
Secondary Air Validation Procedure		
26. Operating instructions specify that secondary air supplies be adjusted during emission tests?	____	____
27. Engineering drawings show secondary air introduced into a chamber distinctly separate from primary chamber?	____	____
28. Validation procedure results demonstrate less than 25 percent change in burn rate?	____	____
29. All procedures and calculations documented?	____	____

General Comments

Figure 11.11. Sheet M28-3.18 (Continued)

Activity	Acceptable	
	Yes	No
Test Fuel Measurements		
30. Moisture content of each test fuel piece measured?	____	____
31. Moisture readings, fuel temperature, and meter correction factors documented?	____	____
32. Test fuel pieces conform to the grade and dimensional specifications required?	____	____
Test Fuel Crib Construction		
33. Test fuel length approximately 5/6 the length of the firebox?	____	____
34. Length of each test fuel piece documented?	____	____
35. Test fuel crib configuration documented?	____	____
36. Test fuel crib meets weight and nominal size specifications?	____	____

General Comments

Figure 11.11. Sheet M28-3.18 (Continued)

Activity	Acceptable	
	Yes	No
Pretest Facility Measurements		
37. Induced draft measured and documented?	____	____
38. Air velocity measured and documented?	____	____
39. Relative humidity measured and documented?	____	____
40. Temperature measured and documented?	____	____
41. Barometric pressure measured and documented?	____	____
Pretest Burn Procedures		
42. Pretest fuel specifications measured and documented?	____	____
43. Ignition procedures documented?	____	____
44. Air supply and fuel adjustments documented?	____	____
45. Air supply controls set a minimum of 15 minutes prior to start of the test run?	____	____
46. Uniform charcoalization achieved?	____	____
47. Pretest fuel weight criteria met?	____	____
48. Surface temperature data recorded?	____	____
49. Blower operated at high or according to manufacturer's instructions?	____	____

General Comments

Figure 11.11. Sheet M28-3.18 (Continued)

WOODHEATER MANUFACTURER: WOODHEATER MODEL:			DATE OF TEST: OPERATOR:					RUN NUMBER: SHEET NUMBER:				FINAL COAL BED WEIGHT:
Time (min)	Test Fuel Scale Reading (lb)	Change in Test Fuel Weight (lb)	Wood Heater Surface Temperature (°F)					Catalyst Temperature (°F)		Room Temp. (°F)	Flue Draft (in. H_2O)	Remarks
			Top	Bottom	Rear	Side	Side	Inlet	Outlet			

Figure 11.12. Sheet M28-4.1 - Test Run Measurements Recording Sheet

Time of Adjustment	Description of Adjustment	Duration of Adjustment

Figure 11.13. Sheet M28-4.2 - Record of the Wood Heater and Test Fuel Adjustments

Test Run/Number[1] (i)	Burn Rate Category	Burn Rate (BR) (dry kg/hr)	Emissions (E_i) (g/hr)	Probability (P_i)	Emission Weighting Factor (K_i)	Weighted Emissions
i = 1, 2, 3, ton.	Cat. 1 <0.80 Cat. 2 0.80 to 1.25 Cat. 3 1.25 to 1.90 Cat. 4 Maximum	Determined from Equation 28-2 (Listed in Ascending Order)	Determined using Equation 5G-5 or 5H-9	Interpolated Probability from Table 28-1 for each Burn Rate	$K_i = P_{i+1} - P_{i-1}$ (e.g., $K_1 = P_2 - P_0$)	$E_i \times K_i$
				$P_0 = 0$		
				$P_1 =$	$K_1 = P_2 - P_0 =$	
				$P_2 =$	$K_2 = P_3 - P_1 =$	
				$P_3 =$	$K_3 = P_4 - P_2 =$	
				$P_4 =$	$K_4 = P_5 - P_3 =$	
				$P_5 =$	$K_5 = P_6 - P_4 =$	
				$P_{n+1} = 1$		
					$\sum_{i=1}^{n}(K_i) =$	$\Sigma(K_iE_i) =$
				Weighted Average Emissions: (g/hr)	$\frac{\Sigma(K_iE_i)}{\Sigma(K_i)} =$	

[1] The test run with the lowest burn rate is assigned test run number 1
The test run with the next lowest burn rate is assigned number 2, etc.

Figure 11.14. Sheet M28-6.1 - Worksheet for Determining the Weighted Average Emission Rate